DIRECT ENERGY CONVERSION
LITERATURE ABSTRACTS

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April 1962

U.S. NAVAL RESEARCH LABORATORY
Washington 25, D.C.

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DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS

Introduction

This is the third in a series of bibliographies covering unclassified literature related to the direct conversion of energy. Subject coverage includes thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and énergy sources.

Users who are primarily interested in thermoelectricity are referred to the four-part bibliography which preceded the present undertaking. Entitled Thermoelectricity Abstracts, it was issued May (PB 151657) and August (PB 151810) 1959, and March (PB 161301) and August (PB 161714) 1960. Copies may be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., by citing the PB numbers included above, following the dates.

The NRL Library does not have copies of the listed material available for outside loan. It is, therefore, suggested that those desiring access to material cited utilize their usual channels for loan or acquisition.

The majority of the publications referred to should be available for consultation or borrowing at the larger public or research libraries. Research reports can usually be obtained from the Armed Services Technical Information Agency (ASTIA), Arlington Hall Station, Arlington 12, Va., through established borrowing procedures, and from the Office of Technical Services (OTS), by purchase. AD numbers are included, when known, in order to facilitate use of ASTIA or OTS services.

Reports emanating from U. S. Government agencies may, in some cases, also be available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. (Check the Monthly Catalog, U. S. Government Publications and its indexes for availability). The Office of Technical Services, Washington 25, D. C., will, upon application, attempt to obtain U. S. Government-sponsored research reports not obtainable elsewhere.

Translations, when referenced, are usually indicated to be available from SLA (Special Libraries Association Translation Center, located at the John Crerar Library, 86 East Randolph Street, Chicago, Ill.) or from LC (Library of Congress, Washington 25, D. C.). Complete information regarding such translations may be found in the issue of Technical Translations designated in the citation.

Suggestions concerning this bibliography are encouraged by the compiler, Miss Mildred Benton, Consultant in Research Information, U. S. Naval Research Laboratory, Code 2023, Washington 25, D. C.

ABBREVIATIONS USED IN CITATIONS TO PERIODICALS

The following is a list of abbreviations used in citing references to periodicals, followed by the complete title of the periodical.

Acad. Bulg. Sci. Compt. Rend.	Académie Bulgare des Sciences Comptes Rendus
Acad. Ray. Belg. Bull. Class. Sci	Académie Royale de Belgique Bulletin de Classe de Sciences
Acad. Sci. Paris. Compt. Rend.	Académie des Sciences, Paris. Comptes Rendus Hebdomadaires des Séances
Acta Electron.	Acta Electronica
Aero-Space Eng.	Aero-Space Engineering
Aerospace Manag.	Aerospace Management
Agr. Eng.	Agricultural Engineering
Air Cond. Heat & Vent.	Air Conditioning, Heating and Ventilating
Akad. Nauk. SSSR. Dok.	Akademiya Nauk, SSSR. Doklady
Akad. Nauk. SSSR. Ser. Fiz. Izvest.	Akademiya Nauk SSSR. Seriya Fizicheskaya Izvestiya
Akad. Nauk. Ukrain. SSR. Voprosy Poroshkovoi Met. i Prochnosti Materialov.	Akademiya Nauk Ukrainskoi SSR. Voprosy Poroshkovoi Metallurgii i Prochnosti Materialov.
Akust. Zhurn.	Akusticheskiy Zhurnal
Am. Acad. Arts Sci.Proc.	American Academy of Arts and Sciences. Proceedings
Am. Aviat.	American Aviation
Am. Ceram. Soc. J.	American Ceramic Society. Journal
Am. Chem. Soc. J.	American Chemical Society. Journal
Am. Electrochem. Soc. Trans.	American Electrochemical Society. Transactions
Am. Gas. Assoc. Mon.	American Gas Association Monthly
Am. Gas. J.	American Gas Journal
Am. Inst. Elec. Engrs. Trans.	American Institute of Electrical Engineers. Transactions
Am. J. Sci	American Journal of Science
Am. Nuclear Soc. Trans.	American Nuclear Society. Transactions
Am. Phys. Soc. Bull.	American Physical Society. Bulletin
Am. Soc. Nav. Engrs. J.	American Society of Naval Engineers. Journal
Ann. Mines	Annales des Mines
Ann. Physik	Annalen der Physik
Appl. & Indus.	Applications and Industry
Appl. Mech. Rev.	Applied Mechanics Review
Appl. Sci. Res.	Applied Scientific Research
Arch. Forum	Architectural Forum
Archiv. Kem.	Arkiv-för Kemi
ARS. J.	ARS Journal
Assoc. Ing. Elect. Sortis de l'Inst. Electrotech. Monteflore Bull.	Association des Ingenieurs Electriciens Sortis de l'Institut Electrotechnique Monte Flore (Bezkrovny) Bulletin
Atlantic Mon.	Atlantic Monthly
Atom u. Strom	Atom und Strom
Atomic En. Soc. Japan. J.	Atomic Energy Society of Japan. Journal
Australian J. Phys.	Australian Journal of Physics

Automotive Indus.	Automotive Industries
Automatic Contr.	Automatic Control
Aviat. Age	Aviation Age
Aviat. Wk.	Aviation Week
Aviat. Wk. & Space Tech.	Aviation Week and Space Technology
Battelle Tech. Rev.	Battelle Technical Review
Beama J.	Beama Journal
Bell Tel. Mag.	Bell Telephone Magazine
Birmingham Univ. Chem. Engr.	Birmingham University Chemical Engineer
Brit. Chem. Eng.	British Chemical Engineering
Brit. Inst. Radio Engrs. J.	British Institute of Radio Engineers. Journal
Brit. J. Appl. Phys.	British Journal of Applied Physics
Bull. Info. Sci. & Tech. Paris	Bulletin d'Information Scientifique et Technique, Paris
Bus. Wk.	Business Week
Byull. Izobretenii	Byulleten Izobretenii Patentnago Upravlenija Komiteta
Can. Electron. Eng.	Canadian Electronic Engineering
Carnegie Tech.	Carnegie Technical
Ceram. Age	Ceramic Age
Cert. Engr.	Certificated Engineer
Chem. & Eng. News	Chemical and Engineering News
Chem. Age	Chemical Age
Chem. & Indus.	Chemistry and Industry
Chem. Eng.	Chemical Engineering
Chem. Eng. Prog.	Chemical Engineering Progress
Chem. Listy	Chemické Listy
Chem. Process Eng.	Chemical Process Engineering
Chem. Wk.	Chemical Week
Comm. & Electron	Communication and Electronics
Commonwealth Engr.	Commonwealth Engineer
Compressed Air Mag.	Compressed Air Magazine
Contemp. Phys.	Contemporary Physics
Contr. Eng.	Control Engineering
Coop. Elec. Res.	Cooperative Electrical Research
Czechoslov. J. Phys.	Czechoslovakian Journal of Physics
Dissertation Abs.	Dissertation Abstracts
Elec. Comm.	Electrical Communication
Elec. Eng.	Electrical Engineering
Elec. J.	Electric Journal
Elec. Mfg.	Electrical Manufacturing
Elec. Rev.	Electrical Review
Elec. Times	Electrical Times
Elec. World	Electrical World
Electrochem. Soc. J.	Electrochemical Society. Journal
Electrochem. Soc. Trans.	Electrochemical Society. Transactions
Electrochim. Acta	Electrochimica Acta
Electromech. Design	Electromechanical Design
Electron.	Electronics
Electron. Design	Electronic Design
Electron. Eng.	Electronic Engineering
Electron. Equip.	Electronic Equipment
Electron. Equip. Eng.	Electronic Equipment Engineering
Electron. Indus.	Electronic Industries
Electron. Indus. & Tele-Tech	Electronic Industries and Tele-Tech.

Electron. Tech.	Electronic Technology
Electron. Wk.	Electronic Week
Electron. World	Electronic World
Electro-Tech.	Electro-Technology
Electrotech. Lab. Bull. (Tokyo)	Electrotechnical Laboratory Bulletin (Tokyo)
Elektron. Rund.	Elektronische Rundschau
En. Nucleaire	Energie Nucleaire (France)
Eng.	Engineering
Eng. & Mining J.	Engineering and Mining Journal
Engr.	Engineer (London)
Engrs. Dig.	Engineers Digest
ETZ	Elektrotechnische Zeitschrift
Fiz. Met. i Metalloved.	Fizika Metallov i Metallovedeniya
Fiz. Tverdogo Tela.	Fizika Tverdogo Tela
Frank. Inst. J.	Franklin Institute. Journal
Fuel Effic.	Fuel Efficiency
Georgia Tech. Engr.	Georgia Tech Engineer
Heat.	Heating
Helv. Phys. Acta	Helvetica Physica Acta
Hiroshima Univ. Fac. Eng. Bull.	Hiroshima University. Faculty of Engineering. Bulletin
Hydrographic Rev.	Hydrographic Review
Illum. Eng. Soc. Trans.	Illuminating Engineering Society. Transactions
Indian Inst. Metals. Trans.	Indian Institute of Metals. Transactions
The Indicator (ACS)	The Indicator (American Chemical Society. N.J. Chapter)
Indus. Eng. Chem.	Industrial and Engineering Chemistry
Indus. Labs.	Industrial Laboratories
Indus. Sci. & Eng.	Industrial Science and Engineering
Ing.	Ingenieur
Ing. Vetens. Akad.	Ingeniors Vetenskaps Akademien
Inst. Elec. Engrs. J.	Enstitute of Electrical Engineers. Journal
Inst. Elec. Engrs. Proc.	Institution of Electrical Engineers. Proceedings
Inst. Franc. Petrole & Ann. Combus. Liquides. Rev.	Institute Francais du Pétrole et Annales des Combustibles Liquides. Revue
Inst. Heat. & Vent. Engrs. J.	Institute of Heating and Ventilating Engineers. Journal
Inst. Radio Engrs. Proc.	Institute of Radio Engineers. Proceedings
Inst. Radio Engrs. Trans CP	Institute of Radio Engineers. Transactions. Professional Group on Component Parts
Instr & Contr. Sys.	Instruments and Control Systems
Instr. Construction	Instrument Construction
Instr. Soc. Am. J.	Instrument Society of America. Journal
Inzhen. Fiz. Zhurn.	Inzhenerno-fizicheskii Zhurnal.
Iron & Steel Inst. J.	Iron and Steel Institute. Journal
Izvest. Sektora Platiny i Drug. Blagorod. Metall. Inst. Obshchei i Neorg. Khim. Akad. Nauk. SSSR.	Izvestiya Sektora Platiny i Drugikh Blagorodnykh Metallov, Institut Obshchei i Neorganischeskoi Khimii imeni N.S. Kurnakova, Akademiya Nauk SSSR
J. Appl. Phys.	Journal of Applied Physics
J. Chem. Ed.	Journal of Chemical Education
J. Chem. Phys	Journal of Chemical Physics

J. Electron. & Contr.	Journal of Electronics and Control
J. Four. Elec.	Journal du four Electrique et de L'ectrolyse
J. Geophys. Res.	Journal of Geophysical Research
J. Heat Transfer	Journal of Heat Transfer
J. Nuclear En.	Journal of Nuclear Energy
J. Phys et Radium	Journal de Physique et le Radium
J. Phys. Chem.	Journal of Physical Chemistry
J. Sci. Instr.	Journal of Scientific Instruments
J. Space Flight	Journal of Space Flight
Kyltek. Tid.	Kylteknisk Tidskrift (Refrigeration Journal
Latv. PSR. Zinat. Akad. Vestis	Latvijas PSR Zinatnu Akademijas Vestis
Mach. Design	Machine Design
Mat. Design Eng.	Materials in Design Engineering
Mat. Handling Eng.	Material Handling Engineering
Mech. Eng.	Mechanical Engineering
Mech. World and Eng. Record	Mechanical World and Engineering Record
Mil. Sys. Design	Military Systems Design
Missile Design & Devlpmt.	Missile Design and Development
Mon. Weather Rev.	Monthly Weather Review
Motortech. Z.	Motortechnische Zeitschrift
N. E. Coast Inst. Engrs. and Shipbuilders. Trans.	North-east Coast Institution of Engineers and Shipbuilders. Transactions.
NTZ	Nachrichtentechnische Zeitschrift
Natl. Acad. Sci. Proc.	National Academy of Sciences. Proceedings
Natl. Res. Devlpmt. Corp. Bull.	National Research Development Corporation. Bulletin
Naturw.	Naturwissenschaften
Nav. Res. (Rev.)	Naval Research (Reviews)
Northwestern Engr.	Northwestern Engineer
NRC Canada. Radio Elec. Eng. Div. Bull.	National Research Council. Canada. Radio and Electrical Engineering Division. Bulletin
Nuclear En.	Nuclear Energy
Nuclear Sci & Eng.	Nuclear Science and Engineering
N. Y. Times	New York Times
Ohio J. Sci.	Ohio Journal of Science
Oil and Gas J.	Oil and Gas Journal
Onde Elec.	Onde Electrique
Petrol	Petroleum
Petrol Wk.	Petroleum Week
Phil. Mag.	Philosophical Magazine
Philips Res. Rept.	Philips Research Report
Philips Tech. Rev.	Philips Technical Review
Phys. & Chem. Solids	Physics and Chemistry of Solids
Phys. Fluids	Physics of Fluids
Phys. Rev.	Physical Review
Phys. Rev. Ltr.	Physical Review Letters
Phys. Soc. Japan. J.	Physical Society of Japan. Journal
Phys. Soc. Proc.	Physical Society (London). Proceedings
Phys. Today	Physics Today
Plant & Power Services Engr.	Plant and Power Services Engineer
Popular Mech.	Popular Mechanics
Power Eng.	Power Engineering
Pribory i Tekh. Eksp.	Pribory i Tekhnika Eksperimenta
Prod. Design	Product Design

Prod. Eng.	Product Engineering
Przeglad Tech.	Przeglad Techniczny
Radio-Electron.	Radio-Electronics
Radiotekh. i Elektr.	Radiotekhnika i Elektronika
RCA Rev.	RCA Review
Refrig. Eng.	Refrigeration Engineering
Rept. NRL Prog.	Report of NRL Progress
Res.	Research
Res. Appl. Indus.	Research; Applied in Industry
Res. Counc. Israel. Bull.	Research Council of Israel. Bulletin
Res. Devlpmt.	Research Development
Rev. Sci. Instr.	Review of Scientific Instruments
Roy. Aero. Soc. J.	Royal Aeronautical Society. Journal
Roy. Soc. London. Proc.	Royal Society of London. Proceedings
Rozpr. Elektrotęch.	Rozprawy Elektrotechniczne
S. Afr. Inst. Elec. Engrs. Trans.	South African Institute of Electrical Engineers. Transactions
Schweiz. Bauz.	Schweizerische Bauzeitung
Sci.	Science
Sci. Am.	Scientific American
Sci. and Mech.	Science and Mechanics
Sci. et Avenir	Sciences et Avenir
Sci. News Ltr.	Science News Letter
Soc. Automotive Engrs. J.	Society of Automotive Engineers. Journal
Solar En.	Solar Energy
Solid-State Electron.	Solid-State Electronics
Solid State J.	Solid State Journal
Soviet Phys. Solid State	Soviet Physics. Solid State
Space/Aero.	Space/Aeronautics
(Die) Tech.	Die Technik
Tek. Tid.	Teknisk Tidskrift
Tele-Tech. and Electron Indus.	Tele-Tech and Electronic Industries
Textile Indus.	Textile Industry
Tids. Kjemi Bergvesen Met.	Tidsskrift for Kjemi, Bergvesen og Metallurgi
Times Sci. Rev.	Times Science Review
Trudy. Nauch. Issled. Inst. Min. Radiotekh. Prom. S. S. S. R.	Trudy. Nauchno-Issledovatelskii Institut Ministertva Radiotekhnika Promyshiennasti S. S. S. R.
Trudy. Ural. Politekh. Inst. im S. M. Kirova	Trudy. Ural skogo Politekhnicheskogo Instituta im S. M. Kirova
Ver. Deut. Ing. Z	Verein Deutsche Ingenieure Zeitschrift.
Voprosy Met. i Fiz. Poluprovodnikov (Moscow. Akad. Nauk. SSSR) Sbornik	Voprosy Metallov i Fiziki Poluprovodnikov (Moscow. Akdemiya Nauk. SSSR) Sbornik.
Wash. Sci. Trends	Washington Science Trends
Westinghouse Engr.	Westinghouse Engineer
Z. Elektrotech. Wien	Zeitschrift für Elektrotechnik (Wien)
Z. Metallk.	Zeitschrift für Metallkunde
Z. Naturforsch.	Zeitschrift für Naturforschung
Z. Physik.	Zeitschrift für Physik
Z. Physik. Chem.	Zeitschrift für Physikalische Chemie
Zavod. Labor.	Zavodskaia Laboratoriia (Moscow)
Zhurn. Fiz. Khim.	Zhurnal Fizicheskoi Khimii
Zhurn. Neorg. Khim.	Zhurnal Neorganicheskoi Khimii
Zhurn. Tekh. Fiz.	Zhurnal Tekhnicheskoi Fiziki

DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS

I. ENERGY CONVERSION
A. General Information

1629
AiResearch Manufacturing Co., Los Angeles, Calif. STUDY AND DEVELOPMENT OF SELECTION CRITERIA FOR OPTIMUM APPLICATION OF ACCESSORY POWER SYSTEMS TO WEAPON SYSTEMS, by R. T. Caldwell, J. T. Ream, et al. 148p., illus., Feb. 1958. (WADC Tech. Rept. 58-462) (Contract AF33(616)3694) (AD-220 969)

A secondary power system is defined to include the power generation equipment, conversion equipment and transmission equipment. The intent of this report is to present data, factors and considerations that can be used by manufacturers in the early design phases of an aircraft or missile to determine the type of system that appears most suitable, from a weight criterion, for the contemplated vehicle.

1630
Aisberg, E. HEAT TO ELECTRICITY. THE KLEIN CONVERTER, A NEW DEVICE FOR DIRECT CONVERSION OF HEAT INTO ELECTRICITY. Radio Electron. 32:58, Mar. 1961.

A "remarkable" invention attributed to Siegfried Klein is discussed in some detail. Working with ionized gas, Klein separates the opposite charges without using any deflecting field, magnetic or electric.

1631
American Power Conference. PROCEEDINGS, March 29-31, Chicago, Ill., vl. 22. 867p., Chicago, Illinois Institute of Technology, 1960.

The following papers have been analyzed: See entries for Erickson, C. R.; Escoffery, C. A.; Harvey, Douglas; Kantrowitz, Arthur; Kirkland, T. G.; and Penrod, E. B.

1632
Bell, L. R. COMPACT ACCESSORY POWER, NEEDED FOR MISSILES. Aviat. Age. 28:30-41, Sept. 1957.

Discussion advocating APU (accessory power unit) design in accessory power systems to meet the requirements of low weight, small size, and packaging flexibility.

1633
Beller, William. ON MANNED FLIGHTS SPACE IS NO PLACE FOR UNTRIED APU'S. TRIED AND TRUE SYSTEMS WITH HEAVY REDUNDANCY WILL FLY WITH MAN TO MINIMIZE RISKS: A REPORT ON ADVANCED R&D. Missiles & Rockets 8:74-75, 102, 104, 106, May 29, 1961.

Diagrams indicate estimated weights of various space power systems, estimated electric power requirements for NASA space missions, and applicability of space auxiliary power sources.

Some observations are made about the state of systems utilizing the chief sources of energy - chemical, solar, and nuclear. The following are discussed: chemical power systems, fuel cells, combustion-type APU's, solar power systems, thermal energy storage, solar-mechanical systems, solar-thermoelectric systems, solar-thermionic systems, and nuclear-power systems.

1634
Bennett, Rawson. NAVY ENERGY NEEDS: PRESENT AND FUTURE. In Seminar on Advanced Energy

Sources, 1958. Proceedings...p. 13-16, Fort Monmouth, N.J., 1959. (Contract DA 36-039-sc-78064) (AD-209301) (PB 151 461)

The need for a source of silent generation of power for ship propulsion is stressed.

1635
Bennett, W. E. THE GENERATION OF DIRECT CURRENT AT HIGH POTENTIALS. Res. Appl. Indus. 7:455-459, Dec. 1959.

The author emphasizes the need for a medium energy machine of high power for use in nuclear research, and he describes a small ionized gas flow high-voltage generator to give a direct current at high potential. Various possible applications for such an apparatus are suggested.

1636
Bierman, Howard. CHEMICAL AND SOLAR POWER SOURCES. Electron. Design 9:51-73, Feb. 15, 1961.

A review is presented of batteries, fuel cells, and solar cells. It includes several tables of data and a comparison between these three energy conversion techniques. (Instr. Abs. 16:3188, 1961)

1637
Bierman, Howard. CONVERTING HEAT TO ELECTRICITY. A STATUS REPORT. Electron. Design 8:32-54, Sept. 28, 1960.

A review of three major areas of the power-source field (thermoelectricity, thermionics and MHD) with information as to what is available, what is being done, and what the future holds.

1638
California Institute of Technology. Jet Propulsion Laboratory, Pasadena, Calif. A SURVEY OF ENERGY CONVERSION SYSTEMS by P. J. Valentine. n.p., 1961. (Tech. Memo. 33-46)

A brief survey is made of the principal types of conversion systems useful for navigation on planetary or space-probe missions. (Astron. Info. Abs. 4:4,039, 1961)

1639
Clay, R. ENERGY CONVERSION IS ON ITS WAY. THERMOELECTRIC GENERATOR, THERMIONIC CONVERTER, FUEL CELL, AND MAGNETOHYDRODYNAMIC CONVERTER. Gas 37:51-55, illus. Apr. 1961.

General information is given on thermoelectric generators, thermionic generators, fuel cells, and magnetohydrodynamic converters.

1640
Clingman, W. H. and Moore, R. G., Jr. APPLICATION OF FERROELECTRICITY TO ENERGY CONVERSION PROCESSES. J. Appl. Phys. 32:675-681, figs., Apr. 1961.

The principles of the conversion of heat energy directly into electrical energy by use of a ferroelectric material heat cycled in the neighborhood of its Curie point are described. A simplified expression for the energy conversion efficiency is derived, and reasonable values for appropriate parameters are used to obtain a numerical value for the efficiency under given operating conditions. The inadequacies of this simplified expression are discussed, and a general expression is derived. The results of the general analysis are compared with those based on the simplified method. The analysis shows that for barium titanate the exact theory predicts a higher efficiency than the simplified theory, and that in general the efficiency increases with increasing externally applied electric field and with increasing heat source temperature. For feasible operating conditions, the efficiency is in the range of 0.5% - 1.0%. Future possibilities for ferroelectric energy converters are discussed.

1641
Conference on Space Technology, Dallas, Tex., April 11-13, 1960. PAPERS. ELECTRICAL ENGINEERING IN SPACE TECHNOLOGY. 133p., New York, American Institute of Electrical Engineers, Dec. 1960.

For analysis of contents, see entries for: Corliss, W. R.; Daniel, A. F.; Duance, J. T.; Hamilton, R. C.; Menetry, W. R.; Thompson, A. W.; and Wilson, G. W.

1642
Daniels, Farrington. CHEMICAL AND BIOLOGICAL MECHANISMS. In Seminar on Advanced Energy Sources, 1958. Proceedings...p.23-34, Fort Monmouth, N. J., 1959. (Contract DA 36-039-SC-78064) (PB 151461) (AD 209301)

Those parts of physical chemistry are summarized which have a bearing on the production and conversion of energy. Laws and limitations are reviewed and new areas of exploration are pointed out.

1643
DeVore, Charles. DIRECT ENERGY CONVERSION. Signal 15:43, 88, 91, May, 15:15-16, June 1961.

Part I is a general information article explaining, first, what direct energy conversion involves, then, describing, in more detail, the four conversion devices receiving the majority of R&D attention — solar cells, fuel cells, thermoelectric generators and thermionic converters.

Part II discusses work being done with a fourth direct energy conversion device, thermionic converters, and describes the SNAP program.

1644
Dryden, H. L., and Von Doenhoff, A. E. SOLAR ENERGY IN THE EXPLORATION OF SPACE. Natl. Acad. Sci. Proc. 47:1253-1261, Aug. 1961.

For amounts of power from a few watts to a few hundred watts, silicon solar cells seem to be a reliable, convenient source of power in space. Such power levels appear adequate for minimum communication needs for missions as far as Mars. The generation of larger amounts of power from a solar turboelectric system, such as Sunflower I, appears feasible but remains to be demonstrated. For power levels of many kilowatts or megawatts as may be required for electrical propulsion, nuclear energy sources and appropriate conversion systems will probably be required.

1645
Eagle, B. A. UNCONVENTIONAL METHODS OF GENERATING ELECTRICAL POWER. S. Afr. Inst. Elec. Engrs. Trans. 51:233-252, Nov. 1960.

A review is given of methods that have been proposed for the "direct" generation of electricity from other forms of energy by methods other than the conventional systems and of experimental devices designed to test the practicability of such proposals. The basic limitations in any energy conversion process are explained and the shortcomings of conventional generation are discussed. Unconventional methods are classified as: (a) electrochemical conversion, (b) photoelectric conversion, (c) solid-state devices, and (d) use of high-velocity ionized gas. Each of these is discussed in turn with particular emphasis on trying to give a simple physical explanation of the processes governing the operation of each type of device and of the fundamental limitations to efficiency of conversion in each case. (Fuel Abs. & Current Titles 2:2348, 1961)

1646
Egli, P. H., and Connelly, J. J. THERMOELECTRIC AND THERMIONIC ENERGY CONVERSION. In Navy Science Symposium, 5th, Annapolis, Md., April, 1961. Naval Research, Proceedings, vl. 2, p. 433-452, Washington, D. C., Office of Naval Research, Dept. of the Navy, 1961. (ONR-9, vl. 2)

Results of current materials research program are detailed; currently feasible thermoelectric applications are listed; and some information is given regarding the program in the field of thermionic energy conversion.

1647
Electro-Optical Systems, Inc., Pasadena, Calif. AN ANALYSIS OF SOLAR ENERGY UTILIZATION.

Volume II. Part III. TECHNICAL ANALYSES, by J. H. Fisher. 340p., Feb. 1959. (WADC Tech. Rept. 59-17, vl. 2, pt. 3, sect. 1-6) (Contract AF33(616)5564) (AD-226 300)

Contents: flat-plate solar collectors, concentrating solar collectors, photovoltiac converters, thermopiles and thermionic emitters, energy storage, and solar distillation techniques.

1648
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume I, GENERAL SYSTEMS CONSIDERATIONS, by W. R. Menetrey and J. H. Fisher. 136p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. 1) (Contract AF33(616) 6791) (AD-257 357) (PB 171 858)

Contains the detailed table of contents for all volumes and general introductory topics for space-related power systems technology.

1649
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume II: HEAT EXCHANGERS, by A. Haire and L. Hays. 286p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. VII) (Contract AF33(616) 6791) (AD-256 881)

Volume VII presents empirical and analytical equations describing the performance of several types of heat exchangers useful in space power systems, including non-phase-change heat exchangers, condensers, boilers, sub-cooling mechanisms, and others. The present state-of-the-art concerning materials compatability, fabrication techniques, knowledge of environmental deterioration, and other factors is presented. Anticipated weights and practical difficulties encountered in systems operation are discussed.

1650
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume IX: SOLAR SYSTEM DESIGN, by W. R. Menetrey. 97p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. IX) (Contract AF33(616) 6791) (AD-256 748)

A summary is given of the anticipated performance of solar power systems over the next decade. This summary is based upon the analytical and empirical relationships describing components performance presented in volumes II through VIII. Weight, cost, and reliability estimates are presented for photovoltaic power systems, and weight estimates are given for solar-thermal systems. Thermal converters include thermoelectric discs, thermionic emitters, turbo-generators, and the Stirling engine.

1651
ENERGY CONVERSION GROUP PROBES NEW POWER IDEAS. Electron. 34:2, May 5, 1961.

Brief mention is made of a paper read at the Fifth Navy Science Symposium by Lt. Cdr. F. W. Anders in which were mentioned new approaches under investigation such as: energy conversion from oceanic waves by mechanical and pneumatic means, from elements contained in ocean water by biological means, from gasless fuels by thermoelectric means, and from radioactive materials by radiolysis.

1652
ENERGY CONVERSION RESEARCH. Wash. Sci. Trends 4, no. 21, Aug. 8, 1960.

Advanced Research Projects Agency (ARPA) has won out in Pentagon attempts to control basic research in advanced energy conversion techniques. The program will be known as Project Lorraine; will be headed by Dr. Uhner Liddel. All ideas that have a potential in the conversion of chemical, nuclear and solar energy into power will be scrutinized by ARPA, with the intention of filling "gaps" in current programs. Thiokol Chemical Corporation is studying methods for the conversion

of ocean wave motion to electrical energy.

1653
Erickson, C. R. THE ELECTRIC AUTO. In American Power Conference, Proceedings, March 29-31, 1960, Chicago, Ill., vl. 22, p. 448-464, Chicago, Illinois Institute of Technology Press, 1960.

Storage batteries are a crucial component of an electric vehicle and their advantages and limitations are examined. The fuel cell is pointed out as another concept which may vitally affect electric vehicle development. One possible method of increasing the range of the electric car is through the use of solar cells and thermopiles to convert the radiant energy of the sun to electrical energy to operate the vehicle.

A bibliography of 28 references is included.

1654
Eshelman, R. H. FUTURE POWER SYSTEMS. Iron Age 188:105-112, illus., Jly. 27, 1961.

Refrigerators without moving parts; industrial plants operating from their own self-contained, compact energy converters; space voyages powered by the sun; and unlimited electrical power from fusion of heavy-water atoms—these are some of the dramatic bombs that could explode our conventional technology in years ahead.

1655
Fisher, J. H., and Menetrey, W. R. COMPARISON OF ENERGY CONVERSION SYSTEMS. In Power Sources Conference, Proceedings, 14th, p. 94-96, Red Bank, N.J., PSC Publications Committee, 1960.

A comparison was made of various energy conversion systems (batteries, fuel cells, nuclear- and solar-energy sources, etc.) on the basis of space satellite power requirements. Only nuclear- and solar-energy sources can meet these requirements over long periods of time, and all the possible combinations of conventional energy forms (thermal or electric) and conversion techniques (heat engines, photovoltaic cells, thermionic converters, etc.) with nuclear- and solar-energy sources were evaluated with respect to reliability, weight, availability, growth potential, cost, hazard, and life for 5- and 30-kw systems. The weighted evaluations show that no single system is outstandingly superior or inferior and that choice of a system should be made on the basis of its development. However, the solar Stirling engine and nuclear thermionic systems appear to be desirable for use as 5- and 30-kw systems, respectively. (Nuclear Sci. Abs. 15:11865, 1961)

1656
Fisher, J. H. A SUMMARY OF ENERGY TRANSFORMATIONS. In Seminar on Advanced Energy Sources, 1958. Proceedings...p. 17-21, Fort Monmouth, N.J., 1959. (Contract DA 36-039-SC-78064) (PB 151461) (AD 209301)

Energy sources, classifications, details of energy conversion systems, and figures of merit for evaluating these systems are discussed and their applications considered.

1657
Furnas, C. C. ENERGY SOURCES OF THE FUTURE. Indus. Eng. Chem. 46:2446-2457, illus. Dec. 1954.

All sources of energy are reviewed and research necessary to utilize solar energy is discussed.

1658
Furnas, C. C. FUTURE SOURCES OF POWER. Sci. 94:425-428, Nov. 1941.

A review of the various practical sources of power which includes a section on direct utilization of solar radiation.

A brief review of this talk appears in Eng. 152:4, Jan. 2, 1942.

1659
Fusca, J. A. POWER SOURCES FOR SPACE EXPLORED. Aviat. Wk. 68:235, 237, 239, 241, illus., June 16, 1958.

Space vehicles soon to orbit earth as reconnaissance satellites, probe the far side of the moon, and eventually venture into outer space, will require steadily increasing amounts of electrical power from sources expected to last longer periods of time, weigh less and have less bulk.

1660
FUTURE POWER SOURCES: (UNITED STATES) NAVY LIKES THERMOELECTRICS AND FUEL CELLS. Prod. Eng. 32:9, Feb. 20, 1961.

Thermoelectric generators using series-connected elements and continuous-feed fuel cells are the most promising of the new power sources at present, reports J. T. Hayward of the United States Naval Operations Office (Development). While research in solar cells has been discontinued for lack of growth potential and wide application, the Navy is still interested in flat-plate solar-energy collectors, using thermoelectric elements sandwiched between sheets of Al foil. They are a fifth the weight and a tenth the cost of solar cells; but the efficiency is low, so the collector area must be about three times as large. (Light Metals Bull. 23:61/2202) May 24, 1961.

1661
Gardner, J. W. DIRECT CONVERSION FOR SPECIALISED APPLICATIONS. Elec. Times 139:909-912, June 8, 1961.

The purpose of the article is to make a round-up of some of the less-publicized proposals for direct conversion which, although of marginal interest for large-scale commercial generation, appear promising for specialist applications requiring small units of high reliability in remote locations, e.g., space vehicles. The devices described are: the photovoltaic cell, the mechanoelectric converter, and the fission cell. (Fuel Abs. & Current Titles 2:4350, Jly. 1961)

1662
Gardner, J. W. DIRECT CONVERSION GENERATORS. Elec. Rev. 168:569-574, Mar. 31, 1961.

The author reviews four methods of direct conversion of heat into electricity. They are MHD, thermoelectric, and thermionic generators, and fuel cells.

1663
Georgia Institute of Technology. Engineering Experiment Station, Atlanta, Ga. RESEARCH ON VARIOUS PHENOMENA FOR THE PERFORMANCE OF CIRCUIT FUNCTIONS, by E. J. Scheibner. 43p., illus., May 31, 1960. (Sci. Rept. 6) (Contract AF33(616)6028) (AD-245 465)

A detailed theoretical treatment is given of the thermoelectric effects, absolute thermoelectric power, Seebeck effect, Peltier effect, Thomson effect, and phonon drag. Other solid-state effects discussed are the Zener effect and cyclotron resonance in metals. The description of the ultra-high vacuum system is continued with emphasis on the filament carrier and turret arrangement.

1664
Golding, E. W. THREE UNCONVENTIONAL SOURCES OF ENERGY. Eng. 192:198-199, illus., Aug. 18, 1961.

Of the many under-used sources of energy in the world, three — wind energy, solar radiation, and geothermal energy — are receiving serious attention and are briefly discussed in this article.

1665
Grant, L. J. POWER SOURCES FOR ORBITAL ROCKETS. J. Space Flight 3:1-3, Nov. 1951.

Nuclear and solar sources are discussed.

1666
Hamada, S. DEVELOPMENT AND PROSPECTS OF DIRECT GENERATION OF ELECTRICITY. Genshiryoku Kogyo 7:26, Feb. 1, 1961.

In Japanese. Not examined. (Fuel Abs. & Current Titles 2:3626, June 1961)

1667
Hamilton, R. C., and Laue, E. G. SPACECRAFT SECONDARY POWER REQUIREMENTS DURING THE SIXTIES. In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 112-119, New York, American Institute of Electrical Engineers, Dec. 1960.

A summary of the secondary electric power during the 1960-65 period for a typical spacecraft is shown in a table. For the future, the reactor-powered thermoelectric converter known as SNAP-X which provides 200 to 300 electric watts appears attractive for some missions. Development of more rugged fuel cells for energy storage applications is proceeding, and will be needed during the sixties.

1668
Hart, V. B. ELECTRICITY FOR SPACE VEHICLES. Paper CP-59-978, presented Sept. 23, 1959. New York, American Institute of Electrical Engineers.

Factors such as weight, new sources of electrical energy, long periods of flight, and very large power systems, which contribute to the problem of supplying electricity for space vehicles, are discussed. Research work areas where more effort must be expended are: electric power system design and control, and power conversion. (Astron. Info. Lit. Search. 294, Item 179)

1669
Hayward, J. T. DIRECT ENERGY CONVERSION. SAE International Congress & Exposition of Automotive Engineers, Detroit, Mich., Jan. 9-13, 1961. Preprint 297B, 14p.

Discussion of the design principles and performance characteristics of solar cells, thermionic emission and thermoelectric devices, fuel cells, and magnetohydrodynamic devices. (Intern. Aerospace Abs. 61-2396, Apr. 1961)

1670
HEAT OF DECAY MAKES ELECTRICITY. Bus. Wk. p. 68, May 6, 1961.

Scientists develop another new way to convert the energy of heat directly into electricity. Commercial uses are a long way off, but military applications may be near.

1671
Hoh, S. R. FERROELECTRIC ENERGY CONVERTERS. Elec. Comm. 37:22-26, 1961.

Ferroelectric energy converters (based on effect of temperature on dielectric constant of ferroelectric and related materials) offer unique characteristics such as high alternating and direct voltages. This contrasts to existing heat-to-electricity converters such as thermoelectric and thermionic types. The conversion efficiency will be substantially lower than these latter converters unless material characteristics can be improved.

1672
Institute for Defense Analyses. Advanched Research Projects Division, Washington, D.C. RESEARCH AND DEVELOPMENT ON POWER SOURCES AND ENERGY CONVERSION IN THE DEPARTMENT OF DEFENSE, AEC, AND NASA, by N. W. Snyder. 89p., May 16, 1960 (Tech. Rept. 61-4(U), Abridged version) (Contract SD-50) (AD-257 806)

This study, made for the Office of Fuel, Materials, and Ordnance, DDR7E, indicates the scope of work by the Federal Government and lists the projects supported by the Army, Navy, Air Force, AEC and NASA with brief descriptions of the purpose.

1673
Ioffe, A. F. PHYSICS OF SEMICONDUCTORS. 436p., London, Infosearch Ltd., 1960.

Thermionic emission and thermoelectricity are referred to in a number of instances.

A bibliography of 63 references appears on p. 420-422.

1674
Jones, K. SECONDARY POWER IN ADVANCED FLIGHT VEHICLES. Aero/Space Eng. 18:54-57, 63, Aug. 1959)

Systems are defined here as all electric, hydraulic, and pneumatic power required to operate subsystems. The principal requirements for future national, military, or scientific exploratory systems are reviewed. Systems discussed include: total secondary power required; possible sources of power, including atomic and chemical batteries, solar cells, thermionic converters, thermopile generators, fuel cells, atomic power units (isotope and reactor), and magnetohydrodynamics. A quantitative definition of hyperenvironments for electrical systems is also tabulated.

1675
Jones, R. A. and Keeler, J. S. FLIGHT VEHICLE POWER. Soc. Automotive Engrs. Preprint, 9p. no. 105U, 1959.

The requirements of space power systems for the following purposes are first considered: boost glide vehicle power, short duration satellite (auxiliary) power, electrical thrust power, long duration satellite (auxiliary) power. The way in which these requirements may be met by the following energy conversion systems is then discussed: batteries, fuel cells, chemical dynamic systems, nuclear power systems, and solar power systems. (Index Aero. 17:163, Apr. 1961)

1676
Kamo, Roy. TOMORROW'S POWER SOURCES. Prod. Eng. 32:51-60, June 26, 1961.

Survey of 14 basic power sources suitable for portable machines requiring from 1 to 500 hp. Electric power sources covered include: fuel cells, thermoelectric generators, thermionic converters, MHD generators, and solar cells. Mechanical power sources covered are: spark-ignition reciprocating engines, diesel engines, gas turbines, free-piston engines, rotary engines, Stirling regenerative engines, vapor engines, and chemical "explosive" engines.

1677
Kaprielyan, S. P. and Ainsworth, Marcus. TRENDS IN AUXILIARY POWER. Aerospace Manag. 4:50-53, illus., Aug. 1961.

Tasks assigned to auxiliary power systems are indicated, power conversion methods are charted, and a table lists energy conversion techniques according to form of energy source, ultimate storage potential, and form of energy delivered by system designated.

1678
Kelly, Curtis. FLIGHT VEHICLE POWER FORECASTS. In Snyder, N. W. ed. Space Power Systems, p. 625-632, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

Forecasts of optimum application of energy conversion methods are presented and described. Comment is offered on the more significant problems and intriguing aspects of certain specific energy conversion methods.

1679
Kroms, A. NEW METHODS OF POWER GENERATION. Part 2. Energie 13:11-16, Jan. 1961.

In German. The principles of some new power generating methods (thermoelectric, thermionic, magnetohydrodynamic) are discussed. A brief historical review is given and some experimental installations are mentioned.

1680
Leo, B. S. and Hsu, S. T. A SIMPLE REACTION TURBINE AS A SOLAR ENGINE. Solar En. 4:16-20, figs., Apr. 1960.

This article describes the design improvement and performance of the reaction turbine when operating under vacuum conditions. A method of distilling water and obtaining power simultaneously by using a closed cycle is presented. Also thermoelectric and thermionic power sources are discussed.

1681
Martin, C. G., Dennington, R. J. and Kovucik, V. P. DYNAMIC HEAT ENGINES - FUNDAMENTAL CONCEPTS FOR LIGHT-WEIGHT COMPACT APPLICATION. In Seminar on Advanced Energy Sources, 1958, Proceedings...p. 109-121, Fort Monmouth, N.J., 1959. (Contract DA 36-039-SC-78064) (PB 151461) (AD 209301)

Discussed are possible power plants, selection of vapor engine design points, engine design features, other applications, and areas for research and development.

1682
Maryland University. Bureau of Business and Economic Research, College Park, Md. SOLAR AND ATOMIC ENERGY. A SURVEY. 21p., Mar. 1959. (Studies in Business and Economics, vl. 12, no. 4)

This is a general survey including a section titled "solar energy prospectus (nature of solar energy; selected illustrations; solar power conversion; photochemistry and photoelectricity; storage of energy; and energy transmission)."

1683
Mason, W. P. ENERGY CONVERSION IN THE SOLID STATE. In Seminar on Advanced Energy Sources, 1958. Proceedings...p. 165-179, Fort Monmouth, N. J., 1959. (Contract DA 36-039-78064) (PB 151461) (AD 209301)

Electromechanical and mechanoelectric energy converters are among the types discussed.

1684
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. QUARTERLY PROGRESS REPORT NO. 61. 275p., Apr. 15, 1961. (Contract DA 36-039-SC-78108)

Includes reports on: (1) quantitative analysis of a photoemissive solar-energy converter; and (2) plasma magnetohydrodynamics and energy conversion.

1685
Miller, D. T. A. A COMPARISON OF FOUR AUXILIARY POWER SYSTEMS FOR SHORT DURATION MISSILE APPLICATIONS. 38p., New York, Society of Automotive Engineers, 1960. (Preprint 232A)

The four systems compared are: flywheel, silver-zinc battery, solid propellant, and bottled gas. The mission for which the auxiliary power systems (APS) are required is a duty cycle of 100 seconds at an average output of 10 h.p. A detail evaluation of the APS's is carried out and it is concluded that the bottled gas system is unsuitable, the flywheel and solid propellant systems have a good performance under favorable load conditions only, while the battery system is versatile and requires the minimum development time. (Index Aero. 17:84, May 1961)

1686
Motorola, Inc., Phoenix, Ariz. DEVICES WHICH CONVERT RADIANT ENERGY DIRECTLY INTO ELECTRICAL ENERGY, by M. A. Reichardt, Jr. 14p., illus., 1955. (Memo. 4 in Sci. Rept. 3) (Contract AF33(616)2708) (AD-713119d)

A study of radiant-energy devices was made to determine which devices are applicable as power sources for transistorized equipment. A comparison was made between (a)

thermoelectric generators using either solar or artificial radiation and (b) radioactive and photoelectric power sources. Results indicated that only the solar battery and the radioactive cell will have practical applications for the future.

1687
Newton, J. S. HOW TO SELECT POWER SYSTEMS FOR AEROSPACE APPLICATIONS. Soc. Automotive Engrs. Preprint 232D, 12p., 1960.

A very generalized discussion of factors affecting the selection of auxiliary power systems for use in aircraft and space vehicles. (Index Aero. 17:119, May, 1961)

1688
Ogle, H. M. FRONTIERS IN POWER RESEARCH; DIRECT CONVERSION. Power Eng. 65:57-66, Jan. 1961.

This is a general article giving historical background for generation of electrical power, the incentive for improvement of efficiency and some details concerning direct conversion approaches such as magnetohydrodynamics, thermoelectrics, and thermionics.

1689
Palmquist, N. B. SATELLITE AUXILIARY POWER SYSTEMS. In Planetary and Space Science, vl. 4, Proceedings of the Fourth AFBMD/SRL Symposium. Advances in Ballistic Missile and Space Technology, p. 202-225, New York, Pergamon Press, Jan. 1961.

General requirements of auxiliary power systems are presented, in particular for the Discoverer II vehicle. Preliminary studies, design approaches, and hardware development of the prime energy equipment and power conversion equipment are discussed. The auxiliary power system is formulated, and its flight performance is evaluated. A brief look at future systems such as solar photovoltaic, nuclear, thermoelectric, and high energy batteries is also presented.

1690
POWER SOURCES--OLD AND NEW. Sci. News Ltr. 80:106-107, illus., Aug. 12, 1961.

Atomic reactors are important, but so are the sun, the wind, and underground steam, as scientists seek answers to one of the world's most challenging problems.

1691
Power Sources Conference. PROCEEDINGS, 14th, May 17-19, 1960, 151p., illus., Red Bank, N. J., PSC Publications Committee, 1960.

For papers analyzed see entries for: Blumrich, J. F.; Bone, J. S.; Cherry, W. R.; Clune, R. R.; Dale, B.; Fisher, J. H.; Hernquist, K. G.; Hunger, H. F.; Jensen, A. S.; Kallman, H. P.; McKee, W. E.; Mandelkorn, Joseph; Mann, A. E.; Ogburn, G. H., Jr.; Oster, E. A.; Perry, John, Jr.; Podolny, W. H.; Prince, M. B.; Redemske, R. F.; Stephems, C. W.; Winkler, S. H.; Wynn, J. E.; Wysocki, J. J.

1692
Rand Corp., Santa Monica, Calif. DIRECT POWER CONVERSION. PART I. GENERAL COMMENTS, by J. H. Huth. 10p., Oct. 21, 1957. (Rept. S-68) (Contract AF33(038)-6413) (AD-144 267)

The review includes comments on solar cells, fuel cells, and thermocouples.

1693
Randall, Eric. UNCONVENTIONAL POWER SOURCES. Electro-Tech. 68:54-62, Aug.; 85-94, Sept. 1961.

A survey of the various types of "exotic" power sources that are being developed particularly for use in space vehicles. Part I covers fuel cells and thermoelectric converters; Part II discusses thermionic converters, solar cells and magnetohydrodynamics.

1694
REF Manufacturing Corp., Mineola, N. Y. ELECTRIC POWERED AND

SOLAR POWERED FOOD WARMING UNITS FOR SPACE VEHICLES, by M. H. Rochman, H. S. Siegel, and R. A. Landes. 69p., illus., Dec. 1960. (WADD TR 60-620) (Contracts AF33(616)-6199, AF33(616)-6909) (AD-252 123) (PB 171605)

Two general classes of food warming methods for use aboard a space vehicle were studied; one class using electrical energy, the other using direct thermal energy. Electrical heating methods investigated were electromagnetic, ultrasonic energy electrically-produced, and electrical resistance; direct thermal energy sources evaluated were nuclear, solar, chemical, and a heat pump system. Electrical resistance heating, utilizing direct conductance to transfer heat to the food, was considered the most feasible of the electrical methods, and solar heat-sink the most feasible of the direct thermal methods. Each preferred method appeared to be the most compact, reliable, economical, and safe in relation to the energy source employed. The development and final design features of an electric powered food warmer and a solar powered food warmer are covered in Part II.

1695
Richter, H. L., Jr. ELECTROMAGNETIC ENERGY MECHANISMS. In Seminar on Advanced Energy Sources, 1958. Proceedings...p. 31-34, Fort Monmouth, N. J., 1959. (Contract DA 36-039-SC-78064) (PB 151461) (AD 209301)

A brief review is presented of some of the fundamental subjects involved in the transport of energy by means of electromagnetic radiation, beginning with a basic discussion of the forms and sources of electromagnetic energy and ending with suggestions for possible application.

1696
Ross, D. P. SPACE POWER TRENDS. Paper presented at National IAS/ARS Joint Meeting, Los Angeles, Calif., June 13-16, 1961. 23p. New York, American Rocket Society, 1961. (Paper 61-191-1885)

During the next ten years, the electrical space-power requirements will vary from watts to megawatts for a multitude of missions. These include Earth orbital, lunar, and interplanetary missions of varying complexity. The power requirements and duration of the space missions anticipated during the next decade are enumerated. Power systems capable of satisfying these requirements are the battery, fuel cell, solar photovoltaic arrays, chemical and cryogenic electromechanical power units, nuclear and solar turboelectric systems, nuclear direct-conversion systems, and the solar thermionic system. The boundary of applicability of these systems to the projected missions is presented. A description of the trend in design and performance of these powerplants and the anticipated modification in component design is given.

1697
Sandelman, S. L. and McJones, R. W. EVALUATING APU SYSTEMS FOR SPACECRAFT. Space/Aero. 31:86, 88, 90, 92, 94, 97, illus., Mar. 1959.

The choice of auxiliary power systems for space vehicles is bewilderingly wide—it ranges all the way from such standbys as the silver-zinc battery to "blue sky" solar and nuclear devices. Which approach is best for which mission? A review of APU systems points the way to the answer to this question.

1698
SCIENCE AND INDUSTRY. THE ATLANTIC REPORT. Atlantic Mon. 205:24-32, May 1960.

In this non-technical article three approaches to thermoelectricity are discussed: (1) thermoelectric generator based on the "device that controls the temperature of an autdmatic hot-water heater;" (2) thermionic converter utilizing an effect first observed by Edison; (3) magnetohydrodynamics based on the same principle as the conventional

generator of Faraday. Each of these approaches is discussed in some detail as are semiconductors and mixed valence compounds. Westinghouse's work on a 5000-watt generator (mixed valence compound which operates from 850° to 1500°F) for the Navy and a 100-watt generator for the Air Force (weighs 40 pounds and is heated by propane gas - TAP-100) are mentioned. RCA's work on a 270-watt thermionic converter with Ce vapor to control the space charge is discussed in terms of utilizing heat from the sun or waste heat from a rocket motor. GE has developed a similar cell, but the space charge is controlled by having the plates extremely close together. Thermo-Electron Engineering, General Dynamics, and Los Alamos Scientific Laboratory have all achieved similar results with their converters. The magnetohydrodynamic approach of GE, Avco-Everett, and the American Electric Power Service Corporation include tentative plans for central power station use. GE believes that its open cycle MHD generator may be ready for satellite use by 1961.

1699
Seminar on Advanced Energy Sources and Conversion Techniques, Pasadena, Calif., 1958. PROCEEDINGS... sponsored by the U.S. Department of Defense in cooperation with California Institute of Technology under the auspices of the U.S. Signal Corps. 260p., Fort Monmouth, N.J., 1959. (Contract DA 36-039-SC-78064) (PB 151461) (AD 209301)

For analysis of contents see entries under the following: Trudeau, A.G., Bennett, Rawson; Fisher, J.H.; Daniels, Farrington; Richter, H. L., Jr.; Miller, P. H., Jr.; Hamer, W. J.; Morehouse, C. K.; Martin, C. G. et al; Duwez, Pol; Rappaport, Paul; Coleman, J. H., White, D. C. and Riaz, Mahmoud; Mason, W. P.; Rosa, R. J. and Kantrowirz, Arthur; Kallman, H. P.; Von Doenhoff, A. E. and Hallissy, J. M., Jr.; Rosenblum, Louis and English, R. E.

1700
Sherman, G. W. FORECASTS FOR FLIGHT VEHICLE POWER. SAE International Congress & Exposition of Automotive Engineers, Detroit, Mich., Jan. 9-13, 1961, Preprint 297C. 7p.

Review of Air Force sponsored research on future auxiliary power systems, including developments and trends in cryogenic dynamic power systems, fuel cells, photovoltaic power systems, thermoelectric and thermionic conversion devices, and solar dynamic systems. (Intern. Aerospace Abs. 61-2390, Apr. 1961)

1701
Smithells, C. J. METALS REFERENCE BOOK, vl. II. New York, Interscience Publishers, Inc., 1955.

Thermoelectric properties and temperature measurement, p. 652-658; Thermionic, photoelectric and secondary emission, p. 668-670.

1702
Snyder, N. W., ed. ENERGY CONVERSION FOR SPACE POWER. A Selection of Technical Papers Based Mainly on a Symposium of the American Rocket Society held at Santa Monica, California, September 27-30, 1960. 779p., illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3)

For analysis of contents see: Bowman, M. G.; Denney, J. M.; Henderson, R. E.; Kerr, D. L.; McCune, J. E.; Queisser, W. B.; Roes, J. B.; Schulman, I. M.; Steele, H. L.; Sutton, G. W.; Way, Stewart; and Wolf, Martin.

1703
Synder, N. W. POWER SUPPLIES FOR SPACE VEHICLES. Astronautica Acta 6:271-310, 1960.

A detailed discussion of the problems associated with the development of electrical power supplies for propulsion purposes and for

auxiliary power. Aspects considered include: power requirements for space, sources of energy, conversion of energy, storage of energy, special problems and special components, advantages and disadvantages of the various systems. (Index Aero. 17:121, May 1961)

1704
Snyder, N. W., ed. SPACE POWER SYSTEMS. 632p., illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

A selection of papers based mainly on a Symposium of the American Rocket Society held at Santa Monica, California, September 27-30, 1960.

Aspects of solar power systems including the work performed for USA space vehicles are discussed. The SNAP program, chemical systems, and space power requirements are also outlined.

For analysis of contents see entries for: Campana, R. J.; Karcher, R. W.; Kelly, Curtis; McClelland, D. H.; Scott, W. C.; Silvers, D. H.; Thiele, A. W.; and Zwick, E. B., in this issue and Bloom, J. L.; Dick, P. J.; Evans, W. H.; Finger, H. B., Greenfield, H. H.; Hamilton, R. C.; Henderson, R. E.; Hirsche, R. L.; Johnson, K. P.; Perry, L. W.; Purdy, D. L.; Rudy, J. A.; Snyder, N. W.; and Winkler, S. H., in preceeding issue.

1705
Sohn, R. L. and Wheater, H. W. ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE DESIGN AND OPERATION OF SPACE VEHICLE POWER SYSTEMS. In Institute of Environmental Sciences. Proceedings 1960, p. 375-398, illus., Mt. Prospect, Ill., Institute of Environmental Sciences, 1960.

Space vehicle power supply requirements are defined and the nature and capabilities of power systems that can meet these requirements are described. Energy sources (solar, nuclear, chemical, and batteries and fuel cells) are discussed.

1706
Spring, K. H. DIRECT GENERATION OF ELECTRICITY. Electron. Wk. 19:11, Jan. 11, 1961.

The current trends of British work are outlined. On economic grounds the CEGB are concentrating their fuel-cell research on to cells which could burn cheap, relatively impure gases for primary generation. There is a large amount of activity in the general field of gas dynamics, and in the more limited field of magnetohydrodynamics generation. The Board and the Rolls-Royce are independently investigating pulsed combustion devices. AERE and the Board are working jointly on a mercury closed-cycle apparatus. The principles of a method using crossed electric and magnetic fields to reduce the effects of space charge are being investigated by thermionic means. (Fuel Abs. & Current Titles 2:2935, 1961)

1707
Spring, K. H. GENERATION OF ELECTRICITY WITHOUT THE USE OF ROTATING MACHINERY. Nature 190:297-299, Apr. 22, 1961.

A number of generation processes are briefly discussed, among them: the fuel cell, magnetohydrodynamic (MHD) generation, thermionic generation, thermoelectricity, thermomagnetic generation, ferroelectric generation, photovoltaic converters (solar cells), and piezoelectric converters.

1708
Stone, Irving. SURVEYOR LUNAR SPACECRAFT HAS VARIED APPROACHES. Aviat. Wk. 74:50-51, 53, 55-56, illus., Jan. 30, 1961.

"Probability is that solar panels will be used as a power source for the lunar package... non-regenerative fuel cells also are being considered as a primary source."

1709
Thompson, A. W. THE ROLE OF ELECTRIC ENERGY IN SPACE APPLICATION. In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 47-51, New York, American Institute of Electrical Engineers, Dec. 1960.

Tables list experiments carried by various satellites powered by solar power supply. Specific examples are given of power requirements for a communications satellite, a lunar exploration program, and the lower limits for electrical propulsion.

1710
Trudeau, A. G. ARMY ENERGY NEEDS, PRESENT AND FUTURE. In Seminar on Advanced Energy Sources, 1958. Proceedings...p. 7-11, Fort Monmouth, N.J., 1959. (Contract DA 36-039-SC-78064) (PB 151461) (AD 209 301)

In summary, the needs are: increasing amounts of energy from both recognized and advanced sources; mobile, rugged, noiseless, reliable and capable of operating under wide climatic variations; power sources including self-contained energy sources; fuels better than hydrocarbons.

1711
UNCONVENTIONAL POWER SOURCES. Electron. Indus. 19:102-116, Sept. 1960.

The search for new ways to generate electricity is concentrated on six basic conversion devices: (1) magnetohydrodynamic generators, (2) fuel cells, (3) thermoelectric generators, (4) thermionic generators, (5) nuclear batteries, (6) solar cells. As practical devices emerge from this research, electronic equipment will be moving into areas, both on earth and in space, where they were heretofore limited by lack of reliable, long-lived power supplies.

1712
U.S. Department of Defense, Washington, D.C. IMPORTANT AREAS OF ELECTRONIC RESEARCH. A COMPILATION OF STATEMENTS SUBMITTED BY LEADERS IN THE FIELD. 84p., Jan. 1961.

Comments from 14 respondents on various facets of energy generation, storage, and conversion appear on p. 37-41.

1713
Vinsonneau, F. L'ASTRONAUTIQUE ET L'INDUSTRIE. QU'EST QUE L'INDUSTRIE PEUT ATTENDRE DE L'ASTRONAUTIQUE DANS LES PROCHAINES ANNEES? (ASTRONAUTICS AND INDUSTRY. WILL INDUSTRY BE ABLE TO KEEP UP WITH ASTRONAUTICS?). Rev. Francaise d'Astronautique no. 1961-2, p. 45, Mar/Apr. 1961.

Present trends are reviewed including new energy conversion cycles.

1714
Willis. K. E. V. POWER SUPPLIES FOR SPACE VEHICLES. Brit. Inst. Radio Engrs. J. 22:179-188, figs., Sept. 1961.

The requirements for electrical power in space vehicles over the next five years are reviewed and estimated figures given with particular reference to power/weight ratio. Vehicle life duration and its effect on choice of supply are discussed. Problems encountered in space vehicles due to environmental conditions, e.g., temperature, radiation, zero gravity, etc., are pointed out. The available generation methods: thermoelectric generators, thermionic converters, the fuel cell, solar energy nuclear sources, magnetohydrodynamic methods.

1715
Wilson, G. W. A REVIEW OF THERMOELECTRIC, THERMIONIC, AND PHOTOVOLTAIC ENERGY CONVERSION. In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 31-35, New York, American Institute of Electrical Engineers, Dec. 1960.

The status of each of the three methods is surveyed, with the emphasis on thermoelectricity.

1716
WORLD SOLAR PROGRESS. Chem. Wk. 89:38,40,42, Sept. 16, 1961.

A summary of the United Nations Conference on New Sources of Energy, held in Rome, highlights thin film cells, converters, energy storage, and solar furnaces.

1717
Zahl, H. A., Ziegler, H. K. and Daniel, A. F. ENERGY IN SPACE. POUNDS VS. POWER. Chem. & Eng. News 20:96-99.133, May 18, 1959.

Surveys energy sources and power systems which show promise or have already proved capable for space applications. These can be classified into two groups: those which carry within themselves their own source of primary energy, and those which take advantage of natural energy existing in the universe. Solar converters are the only type in the second category at present. The factors affecting the use of these sources in outer space are summarized, and the various energy sources including chemical batteries, fuel cell batteries, nuclear converters, and solar batteries are described.

B. Bibliographies

1718
Brimelow, T. SOLAR ENERGY TECHNOLOGY: 1954-1959. 32p., London, Library Association. (Special Subject List 34)

An attempt has been made to list all of the significant European and American literature. The 329 items are arranged in sections which include: aero/space applications, air-conditioning, automotive engineering, biological science, electrical conversion, furnaces, heating, radio, refrigeration, water heating and water treatment.

1719
California University. Jet Propulsion Laboratory, Pasadena, Calif. THERMIONICS AND THERMOELECTRICITY, by Edda Barber. 185p., Dec. 1960. (Lit. Search 294) (Contract NASw-6)

The 1,000 annotated references pertain, for the most part, to thermoelectricity (theory, properties of materials, Peltier cooling and refrigeration, and thermoelectric generators and systems).

The 148 thermionics references pertain only to vacuum and gas-filled types of power generating devices and energy conversion units.

1720
IBM Corp. Technical Information Service, Endicott, N.Y. BIBLIOGRAPHY OF LITERATURE REFERENCES ON HIGH TEMPERATURE COOLING, WITH SPECIAL EMPHASIS ON THE PELTIER COOLING EFFECT. 3p., Dec. 19, 1956.

20 varied references.

1721
IBM Corp. Technical Information Service, Endicott, N.Y. BIBLIOGRAPHY OF LITERATURE REFERENCES ON THERMOELECTRICITY AND THE PELTIER COOLING EFFECT. 9p., Jly. 1, 1955.

108 varied references.

1722
International Nickel Co., (MOND)Ltd., London, Eng. FUEL CELLS. BIBLIOGRAPHY, compiled by the Technical Information Section. 27p., Sept. 1960.

Current references, with notations, are included.

1723
Jaumot, F. E., Jr. THERMOELECTRIC EFFECTS. Inst. Radio Engrs. Proc. 46:538-554, Mar. 1958.

A review, with over 100 references.

1724
Justi, Eduard. HÖHERE ENERGIEUMWANDLUNG. (HIGH ENERGY CONVERSION) Naturw. 48:537-548, Aug. 1961.

In German. A general review, with about 50 references.

1725
LITERATURE OF THE HEAT PUMP. Elec. World 122:74-77, Sept. 30, 1944.

Bibliography and abstracts of articles published in American and foreign periodicals up to 1944 present summary information on heat pump design and application.

1726
MacDonald, D. K. C. THERMOELECTRICITY. Z. Physik. Chem. 16:310-321, 1958.

A review, in English, with 21 references.

1727
Mawardi, O. K. MAGNETOHYDRODYNAMICS - SURVEY OF LITERATURE. Appl. Mech. Revs. 12:443-446, Jly. 1959.

Processes concerned with manner in which magnetic fields interact with electrically conducting fluids. Review of fundamental considerations covering magnetohydrodynamic waves, magnetohydrostatics, hydromagnetic instabilities, and hydromagnetic shocks. Includes 38 references.

1728
National Bureau of Standards, Washington, D. C. BIBLIOGRAPHY OF TEMPERATURE MEASUREMENT, January 1953 to June 1960. 13p., Apr. 1961. (Monograph 27)

The 500 non-annotated references are grouped under several headings, among them thermoelectric theory and calibration; and thermoelectric, resistance, radiation, and expansion devices.

1729
Nottingham, W. B. and Staff. BIBLIOGRAPHY ON PHYSICAL ELECTRONICS. 428p., Cambridge, Mass., Massachusetts Institute of Technology, Research Laboratory of Electronics, 1954.

An extensive listing of references on thermionic emission appears on p. 204-238.

1730
Raytheon Co. Research Division Library, Waltham, Mass. BIBLIOGRAPHY. GALLIUM PHOSPHIDE: PREPARATION, PROPERTIES AND APPLICATIONS. AN ANNOTATED BIBLIOGRAPHY, by M. S. Kuiper. 21p., Aug. 16. 1961.

Includes about 100 references.

1731
Schreiner, H. and Wendler, F. THEORIES OF SINTERING IN RESPECT OF POWDER METALLURGY PRODUCTION OF THERMOELECTRIC MATERIALS. I. THEORIES OF SINTERING. 2. EXPERIMENTAL METHODS AND RESULTS. Z. Metallk. 52:218-223, 224-228, Apr. 1961.

In German. A survey of literature. 1. Covers theories of sintering advanced by various authors (37 references). 2. Powder metallurgy of thermoelements; reduction of density in sintering; data presented on possibilities of cold compaction of $Bi_2 Te_3$ (17 references).

1732
United Nations. Dept. of Economic and Social Affairs, New York, N. Y. NEW SOURCES OF ENERGY AND ECONOMIC DEVELOPMENT. SOLAR ENERGY, WIND ENERGY, TIDAL ENERGY, GEOTHERMIC ENERGY AND THERMAL ENERGY OF THE SEAS. 150p., illus., 1957.

A selected annotated bibliography appears on pages 119-150.

1733
U.S. Armed Services Technical Information Agency, Arlington, Va.

POWER SUPPLIES. AN ASTIA REPORT BIBLIOGRAPHY. 313p., Jan. 1961. (AD 249 100) (PB 171 689)

This bibliography contains entries from ASTIA's AD collection (1953 to the present) which represent unclassified reports without release limitation. The majority of the 862 references are related to power supplies for space research and technology; entries pertaining to such areas as primary batteries for more conventional application are included. A section on solar radiation is also provided.

1734
U.S. Atomic Energy Commission, Oak Ridge, Tenn. DIRECT ENERGY CONVERSION DEVICES, by H. D. Raleigh. 23p., Mar. 1961. (TID 3561)

Supersedes a previous bibliography entitled "Isotopic Power and Thermionic Conversion" by R. L. Scott, dated December 1959.

Included are 208 references on nuclear direct energy conversion devices. Major emphasis is on auxiliary power devices suitable for use in satellites including reports on nuclear batteries, thermoelectric cells, thermionic conversion, and all phases of the SNAP program.

1735
U.S. Atomic Energy Commission. Office of Isotopes Development, Washington, D. C. RADIOISOTOPES IN WORLD INDUSTRY. ABSTRACTS OF SELECTED FOREIGN LITERATURE. 141p., Jan. 1961. (TID-6613)

A few references on atomic batteries are included.

1736
U.K. Atomic Energy Authority. Atomic Energy Research Establishment, Harwell, Berkshire. THERMOCOUPLES FOR HIGH TEMPERATURE MEASUREMENT, by A. C. Foskett. 17p., 1959. (Bib. 125)

One hundred and six references are given to publications dealing with thermocouples for high temperature measurement, grouped under general theory and design, specific couples, applications and auxiliary apparatus and circuits.

1737
UTILIZATION OF SOLAR ENERGY - LIST OF REFERENCES. Compiled by INSDOC for NISI/UNESCO Symposium on Solar Energy and Wind Power. 17p., New Delhi, 1954.

Literature on the subject up to the beginning of 1954, listing and partially annotating, about 300 references including some 70 patents, according to the following subdivisions: bibliographies, conferences, books, data on solar radiation, utilization in general, engines and boilers, flat plate converters, storage and conversion, solar distillation, solar cookers, hot focus concentrators, research applications, house heating, domestic hot water.

C. Patents

1738
Abbot, C. G. APPARATUS FOR UTILIZING SOLAR HEAT. U.S. Patent 1,801,710, Apr. 21, 1931.

Solar heater with a boiler at the focal point of a reflecting mirror. (Appl. Solar En. Res. p.51, 1955)

1739
Abbot, C. G. SOLAR HEATER. U.S. Patent 1,946,184, Feb. 6, 1934.

Vertical glass pipes, used as heat absorbers, which contain blackened copper plates that conduct the heat. The solar rays are concentrated on the apparatus by means of mirrors. (Appl. Solar En. Res. p.51, 1955)

1740
Bacon, F. T. ALKALINE PRIMARY CELL. U.S. Patent 2,716,670 (E. R. A. Patents, Ltd.), Aug. 30, 1955.

A corrosion-resistant primary cell with low internal resistance. The cell consists of a pair of Ni electrodes whose outer surfaces are in contact

with H and O, and whose inner surfaces are in contact with an alkaline electrolyte. The porous Ni electrode in contact with O is coated with a black Ni oxide into the lattice of which Li has been introduced to increase its conductivity. Conditions for preparation of the electrode are stated.

1741
Bacon, F. T. ELECTRICAL BATTERIES. U.S. Patent 3,002,039 (to National Research Development Corp., London), Apr. 7, 1960.

In a hydrogen-oxygen fuel cell having porous electrodes in which differential pressure between the gases and the electrolyte is balanced by capillary attraction in the pores of the electrodes, the cell being provided with a hydrogen circulation system which includes a condenser for the steam carried by the circulating hydrogen, the improvement comprising a valve for controlling the discharge of condensate from said condenser, means for interrupting the circulation of the hydrogen in said hydrogen circulation system when the condensate reaches a predetermined level in said condenser, and control means responsive to the differential pressure between the electrolyte and the hydrogen for operating said valve to discharge the condensate when the differential pressure drops below a predetermined value.

1742
Betz, P. L. FAST-ACTING THERMOELECTRIC GENERATORS. U.S. Patent 2,992,288 (to Baltimore Gas and Electric Co.), Dec. 31, 1958.

A concentric type thermoelectric device for controlling the flow of current through an electric output circuit comprising inner and outer thermoelements each having one end joined to one end of the other to form a hot junction, said thermoelements having linear thermal expansion coefficients which are approximately equal over the range of operating temperatures to which the hot junction is normally subjected, an electrically conductive body member permanently connected to one side of the output circuit, the opposite end of said outer thermoelement being joined to said body member and forming a first cold junction therewith, a conductor joined to the opposite end of said lower thermoelement and forming a second cold junction therewith, said conductor being permanently connected to the other side of the output circuit, and adjustable electrical contact means for controlling the flow of thermoelectric current through the output circuit including a first contact electrically connected to and actuated by the opposite end of said inner thermoelement, said first contact being movable relative to said first cold junction upon change of temperature of at least one of said thermoelements, a second contact electrically connected to said first cold junction and cooperating with said first contact to provide a shunt path across the output circuit when in engagement with said first contact, and means resiliently biasing said second contact forwardly toward said first contact and to a forwardly stopped position when said contacts are separated and current is flowing through the output circuit.

1743
Broers, G. H. J. FUEL CELL AND METHOD OF PRODUCING ELECTRODES FOR SUCH A CELL. U.S. Patent 2,980,749, Sept. 11, 1958.

In a fuel cell a solid porous carrier of from about 1 mm to about 10 mm in thickness impregnated with a molten mixture of alkali metal carbonates as a semisolid electrolyte having attached to each of its sides a layer of less than 1 mm thick of separate presintered grains of metal powder as electrodes of opposite polarity. (U.S. Pat. Off. Off. Gaz. 765:879, Apr. 18, 1961)

1744
Chapin, D. M., Fuller, C. S., and Pearson, G. L. SOLAR ENERGY CONVERTING APPARATUS. U.S. Patent 2,780,765, Feb. 5, 1957.

Apparatus for converting solar radiation into electrical energy, utilizing a p-n photosensitive cell with a monocrystalline silicon body, which is capable of efficiencies of greater than 5%.

1745
Christian, S. M. RADIATION RESPONSIVE VOLTAGE SOURCES. U.S. Patent 2,847,585, Aug. 12, 1958.

A battery which utilizes the electron voltaic effect in a semiconductor to convert charged or uncharged nuclear radiation directly into electrical energy is described. Each cell of the battery consists of a semiconductor electrode in contact with a metallic electrode such as gold, rhodium, or platinum.

1746
Ciarlariello, T. A. FUEL CELL OPERATION. U.S. Patent 2,997,517 (to M.S.A. Research Corp.), Apr. 22, 1960.

In the operation of a fuel cell comprising a chamber divided into two zones that are in open communication with one another, and where each of said zones contains an electrode and at least one of said electrodes is fluid, the method of preventing direct physical contact between said electrodes during cell operation which comprises feeding to said chamber an electrolyte that is in the fluid state and is of greater density than any other fluid present, and subjecting said electrolyte in said chamber to centrifugal force whereby the electrolyte forms, in each of said zones, a barrier to the passage of either of said electrodes from its zone to the other of said zones. (U.S. Pat. Off. Off. Gaz. 769:988, Aug. 22, 1961)

1747
Claydon, Roy. MANUFACTURE OF THERMOELECTRIC DEVICES. U.S. Patent 2,980,746 (to General Electric Co., Ltd.), Feb. 18, 1959.

A method of manufacturing a thermoelectric device, said method comprising assembling a plurality of thermoelements to form a rectangular array of alternately disposed dissimilar elements, the elements being assembled in a jig, said jig comprising a plurality of intersecting strips forming a rectangular array of cells open at their tops and bottoms, placing in contact with said elements so as to connect the elements in series a plurality of U-shaped rigid metallic bridging members whose ends are fitted into adjacent cells to bridge adjacent elements with the intermediate portions thereof bridging the strips supporting said adjacent cells, disposing said members alternately on opposite sides of the array, coating with soldering material, and then heating the assembly to solder the members to the elements. (U. S. Pat. Off. Off. Gaz. 765:878, Apr. 18, 1961)

1748
DEVICE FOR TRANSFORMING THE ENERGY RADIATED BY RADIOACTIVE MATERIAL INTO ELECTRICAL ENERGY. French Patent 1,193,049 (to Laboratoires d'Electronique et de Physique Appliquées), Apr. 27, 1959.

A nuclear battery is described, consisting of a radioactive source, one or more adjacent luminescent bodies (e.g., silver-activated ZnS), which collect the radiation from said source, and one or more photoelectric cells to convert the luminous energy into electrical energy. (Nuclear Sci. Abs. 15: 9631, 1961)

1749
DEVICES GENERATING ELECTRICITY. French Patent 1,211,016 (to Westinghouse Electric Corp.), Oct. 5, 1959.

The heat developed by nuclear fission is converted partly into electricity in a direct way by means of cylindrical thermoelectric elements. A series of these elements is enclosed between coaxial cylindrical metal envelopes overlapping each other and having a length about

twice that of each thermoelectric element and serving also to connect the elements electrically. The assembly forms a tube into which a nuclear fuel can be introduced, so as to give a nuclear fuel element, which can be cooled by a liquid flowing on the outside. Alternatively a liquid fuel can be situated outside and cooling liquid inside the tube. (Nuclear Sci. Abs. 15:1046, 1961)

1750
Deysher, R. H. THERMOELECTRIC CELL. U.S. Patent 2,310,354 (U.S. Dept. of Commerce), Feb. 9, 1943.

The objective of this invention is to provide cells having a relatively long useful life which are operable satisfactorily at temperatures of the order of about one hundred degrees centigrade as contrasted to other similar types of cells which operate satisfactorily only at much higher temperatures. (Astron. Info. Lit. Search 294, Item 304)

1751
Falkenthal, E. E. PHOTOVOLTAIC CELL. U.S. Patent 2,643,962, June 30, 1953.

An improvement in sensitivity to short wave lengths is made by use of CdO as a current-collecting layer.

1752
Figner, A. I., Zhmud, E. S., et al. THERMOELECTRONIC CATHODE. USSR Patent 134,775, Mar. 29, 1960.

A semiconductor type cathode is said to be activated by Al introduced into the core in amounts 0.3-2.0% or together with powdered core-metal into the emissive layer. (Light Met. Bull. 23:61/3044)

1753
Fisher, J. C. THERMIONIC GENERATOR. U.S. Patent 3,002,116 (to General Electric Co.), Nov. 3, 1958.

An apparatus comprising a conductive cathode electrode and a conductive vaporizable anode electrode spaced from said cathode electrode in a vacuum tight chamber, means for disposing said anode electrode in close proximity to said cathode electrode, said cathode being responsive to the close disposition of the anode thereto and the application of heat thereto to radiate heat to said anode electrode and vaporize the surface portion thereof in proximity to said cathode electrode to form a thin gaseous film under pressure between said electrodes for maintaining the spacing therebetween.

1754
Fritts, R. W. and Karrer, Sebastian. THERMOELECTRIC CONTROL CIRCUIT. U.S. Patent 3,001,126 (to Minnesota Mining and Manufacturing Co.). Aug. 12, 1957.

A thermoelectric generator assembly adapted for connection to a circuit to be energized and having a high temperature coefficient of current output, comprising a first elongated thermoelement, means including a second thermoelement affording a sheath-like enclosure for said first thermoelement and having an end portion, and means within said end portion of said enclosure affording a hot thermojunction joining said thermoelements, said last-mentioned means including a thermistor having a high negative temperature coefficient of resistivity in series circuit with said thermoelements.

1755
FUEL CELL FOR PRODUCTION OF ELECTRICAL ENERGY FROM LIQUID FUELS. British Patent 821,688, Oct. 14, 1959.

The performance of the cell C+O/6N HOHEEtOH/Ni in the form of a double-skeleton electrode was studied, the polarization potential of the electrode being measured in the usual manner against a saturated calomel electrode. It was found to be 1.04 v at 65°, as compared with about 1.09 v for 100% efficiency. At a load of 70 ma/sq/cm. the fuel electrode initially polarized at

0.10 v. The terminal voltage of the cell dropped continuously when a load was maintained over an extended period of time. At a load of 0.09 v, the drop in voltage at the higher load is caused by the slow diffusion of the combustion products which obstruct the pores of the electrode. This difficulty can be decreased either by use of wide-pore electrodes or by agitation of the electrolyte. The average pore diameter should be 20-40 Å, and the inner surface area $\leq$ 30 sq. m/g. The C anode is produced by heating to > 650°, then chilling suddenly to >50°, with one or more repetitions of the heating and chilling process. An H_2O-soluble combustible liquid is mixed with the electrolyte while an H_2O-insoluble combustible liquid, e.g., diesel oil, is emulsified or solubilitized in the electrolyte.

1756
Gorin, Everett. CONVERSION OF CARBON TO ELECTRICAL ENERGY. U.S. Patent 2,570,543, Oct. 9, 1951.

1757
Gorin, Everett and Recht, H. L. POROUS LITHIATED NICKEL OXIDE ELECTRODES FOR FUEL CELLS. U.S. Patent 2,914,596, Nov. 24, 1959.

A lithiated NiO porous sintered body has the necessary corrosion resistance for operation in the air cell of a high-temperature gas-combustion fuel cell. The lithiated NiO is prepared by adding NiO to an aqueous solution of $LiNO_3$ in the amount of 0.1-10 at. % Li. The slurry formed is evaporated to dryness and the residue calcined for several hours at 1000-1300°. The resultant agglomerates are crushed to pass through a 65-mesh Tyler standard screen, and 1-5% ceresin or carnauba wax dissolved in C_6H_6 is added. The mixture is stirred continuously while the solvent is evaporated and calcined for several hours at 1400-1600° while the wax volatilizes. The shaped object is crushed and screened, and that fraction which passes through a 48-mesh screen, but is retained by a 65-mesh screen, is used in the air electrode. These particles are coated with wax as before and pressed at 5000-10,000 lb/sq. in. The compact is fired at 1400-1600° for 8-12 hours. Electrodes 1/16th of an inch thick are produced this way. An electrode having 2 layers of different porosity is made by using 2 different screening fractions treated as above. The layer having finer pores is placed in contact with the molten electrolyte and the layer with the coarser pores in contact with the air chamber. Fuel-cell current and voltage data are given for 4 30-min periods during 2 consecutive days and a 5-hour period during a 3rd day.

1758
Huth, J. H. SOLAR CELL AND METHOD OF MAKING. U.S. Patent 2,993,945 (to Rand Corp.), Feb. 2, 1959.

A solar cell for converting radiant energy into electrical energy comprising a semiconductor junction diode block having parallel opposite first and second outer surfaces with a barrier layer joining p- and n-types semiconductor material extending internally of said block at an angle to each of said outer surfaces in such manner that the depth of one type semiconductor material between said first outer surface and the barrier layer is small at one portion and becomes progressively greater toward a different portion, a metallic contact member fixed to said different portion to make contact with said one type semiconductor material, and a second metallic contact member fixed to said second outer surface to make contact with the other type semiconductor material, said first outer surface being designed to receive said radiant energy. (U.S. Pat. Off. Off. Gaz. 768:973, Jly. 25, 1961)

1759
Imelmann, H. L. THERMOELECTRIC GENERATOR. U.S. Patent 2,987,564 (to Thermo Power, Inc.), Feb. 25, 1958.

In a thermoelectric generator for converting heat energy directly to electrical energy the combination of a cup-shaped insulating support, a plurality of elements each comprising two dissimilar materials having adjacent ends connected together to form a hot junction, insulating means independent of said support for holding said plurality of elements in spaced relationship with all of said junctions disposed in a common plane outside said cup-shaped insulating support, the ends of all said elements remote from said junctions extending into one wall of said insulating support, means for interconnecting said elements in an electric circuit, a pair of terminals mounted on said support, and means for connecting said electric circuit between said terminals. U.S. Pat. Off. Off. Gaz. 767:226, June 6, 1961)

1760
IMPROVEMENTS IN METHOD AND APPARATUS FOR THE DIRECT CONVERSION OF THERMAL TO ELECTRICAL ENERGY. British Patent 854, 036 (to General Electric Co.,), Nov. 16, 1960.

A method of converting thermal energy to electric energy is outlined in which a pair of electrode surfaces with differing work functions is supported in a vacuum-tight enclosure and kept at different temperatures; the electrode with the higher work function is maintained at temperatures above 1400° K and the other at least 700° K below that of the first. Cesium vapor is introduced into the enclosure to coat the cool electrode completely and the hot electrode partially and to neutralize the space charge between the electrodes; in this way, the electrode voltage approaches the contact potential between the two electrode surfaces. In the preferred embodiment of this method, the hot electrode is molybdenum, the cool electrode is oxidized silver, and the support is a ceramic insulator. A plot of the logarithm of electron emission vs. 1/T for various cesium vapor temperatures illustrates the kind of performance that may be obtained. (Nuclear Sci. Abs. 15:6581, 1961)

1761
Johnston, W. D. TITANATE THERMOELECTRIC MATERIALS. U.S. Patent 2,985,700 (to Westinghouse Electric Corp.), June 10, 1959.

A thermoelectric power generating device comprising at least one pair of joined members, one being an n-type member comprised of a material having the formula: $A_xB_{1-x}TiO_3$, wherein A represents at least one element selected from the group consisting of yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium, in the plus 3 valence state, and B represents at least one element selected from the group consisting of calcium, strontium, lead, and barium in the plus 2 valence, and x varies from 0.001 to 0.2, and the other member of the pair being a p-type member electrically connected to one portion of said n-type member. (U.S. Pat. Off. Off. Gaz. 766:1065, May 23, 1961)

1762
Justi, Eduard, Thury, H. J., and Winsel, A. FUEL CELLS. U.S. Patent 2,912,478, Nov. 10, 1959.

A gas electrode having a shaped porous C body with a pore diameter of 10-100 A. and an inner surface area of 10-50 sq/m/g is prepared by rapidly chilling to 50° within one minute, and heating and chilling at least once more. Heating is done in an induction furnace and cooling is accomplished by H_2O quenching. The electrode is used in the process for the direct electrochemical conversion of chemical energy of H, CH_4, and their reaction zone temperature is 20-80°.

1763
Matlow, S. L. and Ralph, E. L. RUGGEDIZED SOLAR CELL AND PROCESS FOR MAKING THE SAME

OR THE LIKE. U.S. Patent 2,984, 775 (to Hoffman Electronics Corp.), Jly. 9, 1958.

The ohmic contact to the n-type part of a Si semiconductor is chiefly Al. (Light Met. Bull. 23:61/3043, Jly. 19, 1961)

1764
Pack, H. G. THERMOELECTRIC GENERATOR. U.S. Patent 2,979, 551, Mar. 2, 1959.

In a device of the type described: a unit thermocouple comprising a metal cylinder; a heat transfer element at the center of the cylinder; a positive current producing element in the cylinder and contacting with the heat transfer element; a negative current-producing element in the cylinder and contacting with the heat transfer element; a current insulating sleeve separating the central heat transfer element and the positive and negative current-producing elements from the metal cylinder; rubber plugs mounted in the ends of the cylinder and adjacent to the positive and negative current-producing elements; and screws mounted in the plugs and being adjustable for contacting with the positive and negative current producing elements for holding them in contact with the heat transfer element; said plugs sealing the cylinder ends to prevent the entrance of air into the cylinder and thereby prevent any damage to the contacting surfaces among the elements due to oxidation caused by air. (U.S. Pat. Off. Off. Gaz. 765:541, Apr. 11, 1961)

1765
Poganski, Siegfried. THERMOELECTRIC SYSTEM. U.S. Patent 2, 993, 080 (to Licentia Patent-Verwaltungs-G.M.b.H.), Jan. 23, 1959.

A thermoelectric system, comprising a first heat-conducting body, a first thermocouple element arm, a second heat-conducting body, a second thermocouple element arm and a third heat-conducting body, all these being stacked one on the other to form a block-shaped body, the contact surfaces between the heat-conducting bodies and the two thermocouple element arms forming cross-section surfaces of the block-shaped body, and a portion of the first and of the third heat-conducting bodies projecting from the block-shaped body in one direction and a portion of the second heat-conducting body projecting from the block-shaped body in the opposite direction; a disc-shaped insulating mass in which said block-shaped body is embedded; said block-shaped body being axially symmetrical to an axis perpendicular to the parallel contact surfaces between said heat-conducting bodies and said thermocouple element arms; the portions of the heat-conducting bodies projecting from said block-shaped body comprising ribs so as to be devised as ribbed heat transfer means, which ribs extend in planes parallel to each other, perpendicular to the disc faces of said insulating mass, and perpendicular to the axis of symmetry of the block-shaped body and wherein the ribbed heat transfer means of the second heat-conducting body in its extension parallel to the disc face of the insulating disc, ends flush with the edge of the disc face of the insulating mass facing the last-mentioned ribbed body. (U.S. Pat. Off. Off. Gaz. 768:724, Jly. 18, 1961)

1766
Rall, D. L. and Giedt, W. H. THERMOCOUPLE. U.S. Patent 2,997,513 (to American Radiator & Standard Sanitary Corp.), Jly. 30, 1957.

The method of determining the temperature within a plate of predetermined material in a predetermined plane within said plate parallel to the faces of said plate comprising: inserting into said plate through one face thereof, and at right angles thereto, a cylinder of a material having the same thermal characteristics as said predetermined material, a thermoelectric element being embedded within said cylinder in said predetermined plane and said thermoelectric element being connected at its ends to leads extending through said cylinder and electrically insulated

therefrom except at their junctures with said thermoelectric element in said predetermined plane. (U.S. Pat. Off. Off. Gaz. 769:987, Aug. 22, 1961)

1767
Roeder, John, Jr. REFRIGERATING APPARATUS. U.S. Patent 2,997, 514 (to Whirlpool Corp.), Mar. 11, 1958.

A thermocouple structure comprising: an enclosure having spaced first and second wall portions; a pair of dissimilar thermoelectric elements within the enclosure each having a first portion adjacent said first wall portion and a second opposed portion; a junction connecting said first element portions including an electrically and thermally conductive spring member having resiliently connected spaced first and second portions, the first portion of the spring member conductively, conjointly engaging said first element portions and the second portion of the spring member engaging said first wall portion, said junction further including a heat transferring member extending from said second portion of the spring member through said first wall portion; and support means supporting said second element portions at said second wall portion. (U.S. Pat. Off. Off. Gaz. 769:988, Aug. 22, 1961)

1768
Sampietro, A. C. THERMAL ELECTROMOTIVE FORCE. GENERATOR. U.S. Patent 2,997,515 (to Thompson Ramo Wooldridge, Inc.), June 27, 1958.

In an electromotive force generator, a sandwich unit comprising first, second and intermediate discs, said first disc being made of a first electrically conductive thermoelectric material and having a flat surface forming a face for confronting one side of said intermediate disc and further including a terminal and assembly post extending away from said face, said second disc and said intermediate disc being centrally aperture and being received on said post, said intermediate disc being made of a second electrically conductive thermoelectric material, an insulating washer interposed between said post and said second and intermediate discs, said second disc being made of said first electrically conductive thermoelectric material and having a flat surface forming a face for confronting the opposite side of said intermediate disc, clamping means including said post clamping said discs tightly together, said clamping means being insulated from said second disc, thereby to form two separate junctions at the respective interfaces between said intermediate disc and said first and second discs, a housing enclosing said sandwich unit, means forming a partition to divide the housing into adjoining chambers, said first disc being seated in an aperture in said partition, and means for supplying heat exchange medium at two different temperatures to the adjoining chambers of the housing to subject said first disc to one temperature and said second disc to a second temperature, thereby to generate an electromotive force at said junctions. (U.S. Pat. Off. Off. Gaz. 769:987, Aug. 22, 1961)

1769
Severy, M. L. APPARATUS FOR GENERATING ELECTRICITY BY SOLAR HEAT. U.S. Patent 527, 379, Oct. 9, 1894.

A reflector directs the sun's heat upon one element of a thermobattery, and the electricity generated by the heated element and a cool element is stored in a storage battery.

1770
Shaffer, L. H. SOLAR THERMOELECTRIC GENERATORS. U.S. Patent 2,984,696 (to American Machine & Foundry Co.), Mar. 9, 1959.

A solar thermoelectric generator, having interior and exterior surfaces, comprising in combination a flat plate receiver, having an inner

and an outer face, adapted to be exposed to solar radiation and to be heated thereby, a transparent cover arranged in spaced relation to said receiver, a support, comprising side wall elements, extending between said receiver and said cover, a plurality of thermocouples disposed between said receiver and said cover with hot junctions of said thermocouples in thermal contact with said cover, means for intercoupling said thermocouples to form an electric circuit and electrical terminals extending from said circuit. (U.S. Pat. Off. Off. Gaz. 766:782, May 16, 1961)

1771

Swanson, J. A. and Horton, P. V. PHOTOVOLTAIC CELL. U.S. Patent 2,986,591 (to International Business Machines Corp.), Oct. 17, 1955.

A photovoltaic cell comprising a body of semiconductive material including a central region of intrinsic material and two contact regions, respectively, of n-type and p-type material, said contact region being joined to said central region by barrier junctions being spaced apart throughout their length by a substantial dimension of said intrinsic material, said dimension being in the range 0.1-0.5 cm and no greater than the transport length of said intrinsic material, said central region having a substantial length in the direction at right angles to said dimension so as to provide a substantial surface area, said central region having a substantial thickness perpendicular to said surface area, said central region, said contact regions and said junctions cooperating, when radiant energy impinges on said surface area, to convert a substantial proportion of said radiant energy to electrical energy. (U.S. Pat. Off. Off. Gaz. 766:1321, May 30, 1961)

1772

Telkes, Maria. THERMOELECTRIC ALLOY. U.S. Patent 2,355,881, Jan. 9, 1945.

Addition of tin and silver in accurately controlled amounts to a zinc-antimony alloy of the approximate composition 35% zinc and 65% antimony.

1773

U.S. Air Force Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base, Ohio. DETECTION DEVICE BY MEANS OF THERMOELECTRIC COUPLES. 11p., illus., Nov. 2, 1960. (Trans. MCL-732 of French patent, 4p., Aug. 27, 1953). (AD-256 191)

The invention pertains especially to the characteristics below and to their various possible combinations: Detector containing thermoelectric couples mounted on an insulating support; the ends of each adjacent thermoelectric couple run into one and the same cell. The detector is characterized in that the ends of each couple running into a cell, are soldered with tin in such a way that the soldering fills said cell; this arrangement makes it possible to obtain perfect solders, to have a plane surface, and to assure complete tightness of the lodging which receives the ends of each thermoelectric couple.

1774

Wallace, C. L., Jr. SOLAR BATTERY AND MOUNTING ARRANGEMENT. U.S. Patent 2,989,575 (to International Rectifier Corp.), Sept. 22, 1958.

A mounting means for a plurality of solar cells; said mounting means comprising first and second heat conductive plates and a spacing and securing means spaced between said first and second plates in spaced parallel relation with respect to one another to form a low mass high strength structure; said plurality of solar cells being mounted over said first plate and being disposed over a predetermined surface portion of said first plate; said solar cells being in thermal connection with respect to said first plate; said first and second plates enclosing a spatial volume; a heat conductive gas; said heat conductive gas being sealed within said spatial volume and conducting heat between said first and second plates. (U.S.

Pat. Off. Off. Gaz. 767:805, June 20, 1961)

1775
Wernick, J. H. SEMICONDUCTIVE MATERIALS EXHIBITING THERMOELECTRIC PROPERTIES. U.S. Patent 2,995,613 (to Bell Telephone Laboratories), Jly. 13, 1959.

A homogeneous semiconductive composition consisting essentially of at least about 5 mol percent to about 90 mol percent of one binary compound selected from the group consisting of lead telluride and lead selenide, remainder at least one ternary compound selected from the group consisting of silver antimony telluride, silver antimony selenide and silver bismuth selenide. (U.S. Pat. Off. Off. Gaz. 769:434, Aug. 8, 1961)

II. THERMOELECTRICITY
A. General Information

1776
Bennett, K. W. THERMOELECTRIC COMES OF AGE. Iron Age 187:70-71, Apr. 6, 1961.

A brief article indicating that "the age of practical thermoelectrics has arrived; thermoelectric units are being sold commercially; companies are doubling R&D outlays; buyers are supplying ideas."

1777
Bonk, J. T. THERMOELECTRICITY. Northwestern Engr. 20:14-15, 30, 31, May 1961.

A review of the basic fundamentals of thermoelectricity is presented, and the development of thermoelectric generators for the SNAP program is cited as an indication of the progress being made to increase the efficiency of thermoelectric elements. (Astron. Info. Abs. 4:40, 185, 1961)

1778
Bradley, F. N. USES AND APPLICATIONS OF THERMOELECTRIC DEVICES AND THEIR IMPORTANCE TO THE CERAMIC INDUSTRY. Ceram. Age. 73:52-53, Apr. 1959.

The emphasis in this article is on ceramic-thermoelectric relations. (1) Single crystals are not essential although they may be preferable. (2) Most promising materials are brittle, but lend themselves to ceramic forming methods. (3) Oxides and carbides may prove to have good thermoelectric properties. Two problems in thermoelectric materials that must be met: (1) a decrease in lattice thermal conductivity is desirable; (2) adding impurity charge carriers to adjust the electronic thermal conductivity to equal the lattice conductivity.

1779
G., W. ON A NEW AND VERY POWERFUL THERMOELECTRIC BATTERY. Am. J. Sci. (2)40:257-258, Nov. 1865.

Refers to description by S. Marcus, of his invention. A note appended to the brief article has historical significance. It states: "The importance of Marcus's invention in a technical point of view can hardly be overestimated, since it promises to furnish the cheapest method of obtaining an intense light for light houses and public buildings, and even holds out a prospect, perhaps not remote, of applications in domestic economy".

1780
G., W. ON THERMOELECTRIC BATTERIES OF REMARKABLE POWER. Am. J. Sci. (2)39:219-220, May 1865.

Elements in the Bunsen and Daniell batteries are compared.

1781
Gardiner, J. W. THERMOELECTRIC GENERATION. Elec. Times 139:163-165, Feb. 2, 1961.

A short introduction to the fundamentals of thermoelectric conversion is given, followed by a discussion of materials suitable for

laboratory and large-scale generation.

1782
Heikes, R. R. and Ure, R. W., Jr. THERMOELECTRICITY: SCIENCE AND ENGINEERING. 576p., illus., New York, Interscience Publishers, 1961.

For analysis of contents, see entries for Bauerle, J. E.; Blount, E. I.; Angello, S. J.; Fein, A. E.; Johnston, W. D.; Keyes, R. W.; Somers, E. V.; Sutter, P. H.; Tiller, W. A.; Ure, R. W., Jr.

1783
International Institute of Refrigeration. PROBLEMS OF LOW TEMPERATURE PHYSICS AND THERMODYNAMICS. PROCEEDINGS OF THE MEETING OF COMMISSION I, Delft (the Netherlands) 1958. 341p., New York, Pergamon Press, 1960.

Some remarks on thermoelectricity are included.

1784
Kelly, John. THE COMING BREAKTHROUGH IN THERMOELECTRICITY. Electronics World 66:39-42, 95, illus., Jly. 1961.

An important new method of energy conversion which promises increasingly widespread applications for power generation, for heating, and for refrigeration without the use of rotating machinery or moving parts.

1785
Kirkpatrick, Paul. A THERMOELECTRIC MOTOR. Phys. Rev. 17:511-512, 1921.

Six silver-germansilver thermocouples operate a small motor when the sun shines on the thermocouples' hot junction.

1786
Lautz, G. THE TECHNICAL EXPLOITATION OF THE THERMAL ENERGY OF METALS AND SEMICONDUCTORS. In Semiconductor Problems, W. Schottky, ed., vl. 4, p. 145-187, Brunswick, F. Vieweg, 1958.

In German. Present knowledge of thermoelectric effects is reviewed in detail. The effective thermoelectric power, which decreases with growing Wiedemann-Franz-Lorenz ratio, is highest in semiconductors of high carrier density, and methods are suggested of further increasing same by doping and alloying techniques. Engineering applications of the Peltier effect for heating and cooling purposes are discussed, also the problems of efficient thermoelectric power generation, i.e., the utilization of the Seebeck effect; an attractive application is the solar thermoelectric generator. (Sci. Abs. 64A: 2427, 1961)

1787
Malevskii, Yu. N. and Ohkotin, A. S. INVESTIGATING SEMICONDUCTOR THERMOELEMENTS. Teploenergetika 2:78-87, 1960.

In Russian. Trans. no. MCL-916 available from Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base, Ohio. (AD-259 625)

Contents: Selecting materials for thermoelements; Preparation of lead telluride; Preparation of the Bi_2Te_3 -Sb_2Te_3 system; Properties of materials and their dependence upon temperature; Technology of preparing thermoelements; Power characteristics of the thermoelements on the base of PbTe and Bi_2Te_3 -Sb_2Te_3 alloys; Specificity of solar thermogenerators.

1788
Massachusetts Institute of Technology. Department of Electrical Engineering, Cambridge, Mass. THEORETICAL AND EXPERIMENTAL RESEARCH ON THERMOELECTRICITY. 129p., Jan. 15, 1961. (Sci. Rept. 4) (AFCRL-122) (Contract AF19(604)-4153) (AD 259 714)

Covers a year's research on the preparation and evaluation of compound semiconductors, on criteria

for the selection of thermoelectric materials, the development of high-temperature measuring apparatus and studies of mechanism of thermal conduction.

1789
THERMOELECTRICITY: U.S. NAVAL RESEARCH LABORATORY CONFERENCE, WASHINGTON, SEPT. 3-4, 1958. Phys. Today 12:26-28, Feb. 1959.

A summary of the conference is presented.

B. Theory

1790
Battelle Memorial Institute, Columbus, Ohio. EVALUATION OF TRANSPORT INTEGRALS FOR MIXED SCATTERNING AND APPLICATION TO GALVANOMAGNETIC EFFECTS, by A. C. Beer, J. A. Armstrong, and I. N. Greenberg. 24p., illus., Mar. 15, 1957. (AFOSR TN 57-87) (Tech. Note 1) (Contract AF18(600) 1547) (AD 120 435)

The Johnson-Whitesell evaluations (Phys. Rev. 89:941, 1953) of the conductivity integrals for mixed scattering have been extended over larger ranges of magnetic field and impurity scattering parameters to allow their application to the high-mobility semiconductors. Values are given for the first thermoelectric integral. Use of the magnetic field dependence of galvanomagnetic and thermomagnetic properties to study charge-carrier scattering is discussed. Applications of the functions in the analysis of Hall effect Corbino magnetoresistance, and thermomagnetic phenomena as functions of magnetic field are illustrated. Also in Phys. Rev. 167:1506-1513, Sept. 15, 1957.

1791
Beal, M. T. VARIATION DU POUVOIR THERMOELECTRIQUE DES ALLIAGES METALLIQUES DU TYPE $CuZn_{\beta}$ EN FONCTION DE L'ORDER. (VARIATION OF THE THERMOELECTRIC POWER OF ALLOYS OF THE BETA-COPPER-ZINC TYPE AS A FUNCTION OF ORDER). Phys. & Chem. Solids 18:150-155, Feb. 1961.

In French. The influence of atomic disorder on the thermoelectric power plotted against temperature, for some alloys, is studied theoretically. In the present paper, it deals with alloys of crystalline structure and thermodynamical behavior similar to those of β brass. Predicts a general lowering of the thermoelectric power and anomalies at the transition point more or less sharply marked. These calculations can be directly transpoed to a magnetic study.

1792
Benedicks, C. THE HOMOGENEOUS ELECTROTHERMIC EFFECT. INCLUDING THE THOMSON EFFECT AS A SPECIAL CASE. Ing. Vetens. Akad. 5:1-27, 1921.

Analyzes the relations among the various thermoelectric effects, i.e., Seebeck, Joule, Peltier, and Thomson effects as well as heat conduction.

1793
Bidwell, Shelford. CHANGES IN THERMOELECTRIC POWER WITH MAGNETISATION. Roy. Soc. London. Proc. 73:413-434, June 22, 1904.

The author discusses the much debated point whether or not magnetization of a material sets up a mechanical compression along the lines of force. He concludes that such a compression does not exist, and is purely mechanical and quite independent of the "Maxwell's stress," if any, which exists. The experimental work of the present paper shows how the thermoelectric power of couples of iron-copper-nickel-copper, and cobalt-copper is influenced by variation in magnetic field. The curves connecting these variables have no resemblance to the curves showing the strain effect of magnetisation, but if to the latter be added the ordinates for the mechanical compression,

$$\frac{B^2}{8\pi \cdot M},$$

a curve is obtained which coincides practically with that for the thermoelectric power. This interesting result is found for iron and nickel, but as to cobalt this coincidence, if it exists, is masked by some cause which has yet to be discovered. As further confirmation of the results, it is found that when the specimen is under considerable stress, the above coincidence still recurs. Thus there is strong evidence in favour of the mechanical compression theory. (Sci. Abs. 7:2283, 1904)

1794
Bohr, N. NOTE ON THE ELECTRON THEORY OF THERMOELECTRIC PHENOMENA. Phil. Mag. 23:984-986, June 1912.

Explains disagreement with O. W. Richardson with respect to the Peltier and Thomson effects.

1795
Bridgman, P. W. THE THERMODYNAMICS OF ELECTRICAL PHENOMENA IN METALS AND A CONDENSED COLLECTION OF THERMODYNAMIC FORMULAS. 244p., New York, Dover, 1961.

Thermoelectric phenomena, p. 39-69; Thermionic phenomena, p. 79-102; Thermoelectric phenomena in crystals, p. 109-131.

1796
De Groot, S. R. THERMODYNAMICS OF IRREVERSIBLE PROCESSES. 242p., New York, Interscience Publishers Inc., 1951.

Ch. VIII, Thermoelectricity, p. 141-162.

1797
Freeman, R. J. DISTRIBUTED SEEBECK EFFECT AT HIGH TEMPERATURES. In High Temperature Thermometry Seminar, October 1-2, 1959, Oak Ridge National Laboratory, p. 53-68, Oak Ridge, Tenn., Oak Ridge National Laboratory, Aug. 1960.

Some brief highlights are conveyed on an effect called "Hot Zone Error". In general summation it is said that hot zone error voltage is a function, among other things, of the type of thermoelectric system or systems used.

1798
Godefroy, L. and Tavernier, J. MAGNETOELECTRIC AND THERMOMAGNETOELECTRIC EFFECTS IN SEMICONDUCTORS. Part I. J. Phys. et Radium 21:249-260, Apr. 1960.

In French. The electrical conductivity of a crystal in the presence of a magnetic field is investigated, by the method of the average energy gain. It is possible to express the current density in tensor form, as a function of the electric and magnetic fields, in the case of a single valley. Also, in the limit of low magnetic field strengths the resistivity and thermoelectric power tensors have been obtained (the latter includes the thermoelectric power proper, the Nernst and thermomagnetoresistance effects). The results are applied to the particular models of germanium and silicon. (Sci. Abs. 64A:8932, 1961)

1799
Godefroy, L. and Tavernier, J. MAGNETOELECTRIC AND THERMOMAGNETOELECTRIC EFFECTS IN SEMICONDUCTORS. Part 2. J. Phys. et Radium 21:544-550, June 1960.

The results of a previous paper are used to calculate the conductivity and thermoelectric power tensors in the general case of a crystal of cubic symmetry. Measurements of the magnetoelectric and thermomagnetoelectric effects are not sufficient to establish the band structure of a cubic crystal. (Electron. Tech. 38:2660, Aug. 1961)

1800
Green, Milton. PRESSURE THEORY OF THE THERMOELECTRIC AND

PHOTOVOLTAIC EFFECTS. Am. Phys. Soc. Bull. 6:28, Feb. 1, 1961.

Abstract only of paper given at the 1961 annual meeting of the American Physical Society, New York, February 1-4, 1961.

"The diffusive force, Fick's plus Soret's, is identified as a pressure gradient. This leads to the following potentials: π, P, and G defined by grad $\pi_\rho = (ep)^{-1}$ x grad P_ρ and $G_\rho = V + \pi_\rho$, where P_ρ is an effective hole pressure, e the electronic charge, p the hole concentration, and V the electric potential. Hole current density I_ρ is given by $I_\rho = -epu_\rho$, grad G_ρ. Identical expressions exist for electrons except that e and μ_n are negative. For isothermal equilibrium $I_\rho = I_n = 0$; hence G = constant. For open circuit, irreversible-steady state, I = 0 and $I_\rho = I_{n+0}$; hence the steady-state electric field is $E = (\text{grad } P_\rho - b \text{ grad } P_n)\mu_\rho p$, where p and b are, respectively, resistivity and carrier mobility ratio. If $P_\rho = pkT$ and $P_n = nkT$, then the potential for isothermal pair-injection (photo) is $V = (b-1)(b+1)^{-1} e^{-1} kT \ln (p_o/p)$; p_o is the equilibrium resistivity. When the pressure gradients are the consequence of a temperature gradient, the expression for E yields for the thermoelectric power:

$$Q = k[\, d(pT)/dt - bd(nT)/dT]\, p\mu_\rho .$$

Phonon interaction gives rise to additional current components given by $I_\rho = -\mu_{\rho\phi}$ grad P_ϕ and $I_n = \mu_{n\phi}$ grad P_ϕ; $\mu_{\rho\phi}$ and $\mu_{n\phi}$ are interaction mobilities and P_ϕ is the phonon effective pressure. The Einstein relationship is satisfied provided $P_\rho = pkT + f(T)$; f(T) is a function of T only." Entire item quoted.

1801

Greene, R. F. SURFACE DEPENDENCE OF THE THERMOELECTRIC POWER IN GERMANIUM AT ROOM TEMPERATURE: THEORETICAL. Am. Phys. Soc. Bull. 6:27, Feb. 1, 1961.

Abstract only of paper given at the 1961 annual meeting of the American Physical Society, New York, February 1-4, 1961.

"A Boltzmann equation treatment is given of the thermoelectric effects associated with excess carriers in the surface space charge region (SSCR) of a semiconductor. In the SSCR, potential variations $\gg kT$ within a mean free path are common so that conductance, thermoelectric power, etc., are nonlocal transport quantities. When these are properly defined, however, the Boltzmann equation treatment of them satisfies the Kelvin-Onsager relation. Constant relaxation times and spherical energy surfaces are assumed to reduce the labor of evaluating the transport integrals. These integrals remain complex because no approximations have been made in the solution of the Poisson equation for the shape of the SSCR. The resulting integrals, which are similar to those arising in the theory of surface mobilities, have been evaluated by electronic computer for various surface scattering conditions and for a range of bulk conditions corresponding to near-intrinsic germanium near room temperatures. Under these conditions the resulting thermoelectric power vs surface conductance curves are unfortunately rather insensitive to the degree of specularity of the surface." Entire item quoted.

1802

Heaviside, O. KELVIN'S THERMOELECTRIC THEORY. Nature 68:78-79, May 28, 1903.

When the theory is extended, considering the current as the curl of the magnetic force of the field, and taking metal-air junctions into account, it is found that Kelvin's $\Sigma pd\theta$ in the metal circuit alone is

a fictitious distribution, which not only gives the same steady current as the real distribution of intrinsic force, but also gives the true E and H everywhere in variable states as well, provided the real intrinsic forces include the metal-air forces along with the Peltier and Thomson forces. (Sci. Abs. 7:138, 1904)

1803
Heikes, R. R. and Ure, R. W., Jr. CLASSICAL AND IRREVERSIBLE THERMODYNAMIC TREATMENT OF THERMOELECTRICITY. In their Thermoelectricity: Science and Engineering, p. 7-18, New York, Interscience Publishers, 1961.

The Kelvin treatment of thermoelectric phenomena is discussed and the reason for its success is investigated. The Onsager approach to the problem is also presented.

1804
Heikes, R. R. NARROW BAND SEMICONDUCTORS, IONIC CRYSTALS, AND LIQUIDS. In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity; Science and Engineering, p. 75-90, New York, Interscience Publishers, 1961.

Transport phenomena is discussed.

1805
Keyes, R. W. and Bauerle, J. E. THERMAL CONDUCTION IN THERMOELECTRIC MATERIALS. In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity; Science and Engineering, p. 91-119, New York, Interscience Publishers, 1961.

The mechanisms are described by which heat transport can take place and the factors which influence it. Only a simple introduction to the subject of thermal conduction is given and its relevance to thermoelectric devices.

1806
Klemens, P. G. A NOTE ON THE THERMOELECTRIC POWER OF MONOVALENT METALS. In International Conference on the Fermi Surfaces of Metals. Proceedings, p. 306-308, New York, Wiley, 1960.

It is shown that the lattice component of the thermoelectric power of monovalent metals must be negative at lowest temperatures, irrespective of the location of the Fermi surface with respect to the zone boundary.

1807
Lucke, W. H. A BRIEF REVIEW AND ANALYSIS OF THERMOELECTRICITY. Rept. NRL Prog. p. 14-27, figs., Apr. 1961.

The three thermoelectric effects are defined and the relations between them are demonstrated for a particular case. They are simply explained on the basis of energy changes of the current carriers and their equilibrium with the lattice. The origin of the "figure of merit", z, in efficiency calculations is shown and its relation to solid-state ideas is presented. The application of these ideas to obtaining better z values is illustrated by a brief description of some of the effects of alloying. The fundamental nature of the problem of higher z values is pointed out.

1808
MacDonald, D. K. C. and Pearson, W. B. THERMOELECTRICITY IN METALS AT NORMAL TEMPERATURES - A QUERY. Phys. Soc. Proc. 78(Pt. 2):306-308, figs., Aug. 1, 1961.

Queries whether a general theoretical reason can be offered for a more or less universal neglect of S_g in comparison with S_e at higher temperatures. If such a reason can be found it would appear to be of considerable importance showing that even at "high" temperatures a rather detailed analysis of collision processes is very essential for electron transport phenomena.

1809
Maclean, M. STRAIN AND THERMOELECTRIC PROPERTIES. Roy. Soc. London. Proc. 64:322-330, 1899.

Kelvin describes in volume 2 of his Mathematical and Physical Papers a number of qualitative experiments to determine the direction of thermoelectric currents in the same metal when one part of it is left unstrained and the other is strained in various ways. The object of the experiments described in the present paper was to determine the magnitude of the thermoelectric effects in similar cases. Junctions were formed between pieces of drawn and undrawn wire made from specimens of copper in different states of purity, and also from lead, reostene, platinoid, German silver, and manganin. The currents produced between the drawn and undrawn portions (one junction being heated in a glycerine bath and the other kept at the temperature of the room) were measured by means of a low resistance galvanometer, and the values in micro-amperes are given by the author. From these were deduced the thermoelectric differences in microvolts per degree difference of temperature. The analyses of the specimens of copper wire and the densities and specific materials are also given in the paper. (Sci. Abs. 2:1177, 1899)

1810

Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. ANISOTROPY OF THERMOELECTRIC POWER IN BISMUTH TELLURIDE, by J. H. Dennis. 52p., Jan. 15, 1961. (Tech. Rept. 377) (Contract DA 36-039-SC-78108) (AD-252 210) PhD Thesis, MIT Dept. Elec. Engineering.

Bismuth Telluride (Bi_2Te_3) has a hexagonal close-packed structure and highly anisotropic electrical and thermal conductivity. However, its thermoelectric-power tensor is only anisotropic under two rather special conditions. It is shown theoretically, on the basis of transport theory for the many-valleyed model of the band structure of Bi_2Te_3, that one way in which the thermoelectric power of this material can be made anisotropic is by causing two scattering mechanisms (lattice and impurity) to operate simultaneously in the material. Iodine-doped n-type material accordingly exhibits an anisotropy of thermoelectric power which is believed to be caused by this mixed scattering, whereas undoped p-type Bi_2Te_3 is found to have isotropic thermoelectric power for any temperature up to room temperature.

The theory also predicts that the thermoelectric power can be made anisotropic if there is simultaneous conduction by holes and electrons. Thus, above room temperature, when intrinsic conduction is setting in, the thermoelectric power of undoped p-type material indeed becomes anisotropic.

Single crystals of Bi_2Te_3 were grown in a crystal puller, and were used to make the necessary measurements of conductivity and thermoelectric power, in both crystallographic directions, over a wide range of temperature. These results of the measurements were in agreement with the predictions of the theory.

1811

Metson, G. H. and Holmes, M. F. THE CONDUCTIVITY OF OXIDE CATHODES. Part 9. THERMOELECTRIC POWER. Inst. Elec. Engrs. Proc. 108C:83-92, figs., Mar. 1961.

By an experimental artifice the present authors show that an apparently complex form of behavior is, in fact, the result of the superposition of two quite simple phenomena. Two parallel-acting thermoelectric power functions are involved, and each of these is invariant with temperature and temperature gradient. The two functions are physically separated and each is measured over an appropriate temperature range. The larger function, of magnitude 2.0 -3.0 mV/deg C, is associated with the vacuum movement of electrons through the hollow pores of the oxide matrix; the smaller one, of

magnitude 0.5 mV/deg C, occurs in the chains of contiguous solid particles of the matrix. Owing to the parallel connection and inequality of these functions, it is concluded that a temperature gradient through an oxide matrix leads to a continuous circulation of current, vacuum-wise in one direction and solid-wise in the other. Since the larger function is essentially one involving thermionic emission of electrons in a vacuum, it can be satisfactorily explained in terms of Richardson's law.

1812
Moizhes, B. Ya. THE INFLUENCE OF THE TEMPERATURE DEPENDENCE OF PHYSICAL PARAMETERS ON THE EFFICIENCY OF THERMOELECTRIC GENERATORS AND REFRIGERATORS. Fiz. Tverdogo Tela 2:728-737, Apr. 1960.

In Russian. Trans. in Soviet Phys. Solid-State 2:671-680, Oct. 1960.

When solving problems dealing with the temperature distribution in the arms of heat generators, it is assumed that the heat conduction current is many times larger than the Joule heat. For refrigerators operating over a small temperature range, a variation of physical parameters is treated as a perturbation.

Excerpts appear in Electron. Express 2:20-22, June 1960.

1813
Ponsot. THERMOELECTRIC POWER AND THOMSON EFFECT. Acad. Sci. Paris. Compt. Rend. 140:1585-1587, June 12, 1905.

In French. Continuing from a previous result, the author arrives at the following conclusion: If a chain of metals, at a temperature lower than the lowest neutral point of a couple formed by any two consecutive metals, be so arranged that a current absorbs heat on passing from one metal to the next on the right, the classification according to decreasing coefficient of Thomson effect is also that in which the thermoelectric power of one metal to the following is positive. (Sci. Abs. 8A:1626, 1905)

1814
Reed, C. J. THERMOELECTRIC AND GALVANIC ACTION. Frank. Inst. J. 146:424-448, 1898.

A comparison of thermoelectric and galvanic action. The author uses the term thermoelectric to include any process in which the electrical energy is derived entirely from external heat. Some examples are given of cells which might appear to be galvanic but are really thermoelectric. Among these is included the Jacques cell. A. E. Kenelly pointed out in the discussion that efficiency forms a criterion by which galvanic action may be judged, and was of the opinion that a cell depending upon heat for its energy, like the Jacques cell, was not necessarily thermoelectric. Experimental evidence was required. J. W. Richards expressed the opinion that ordinary thermochemical data do not apply at the temperature of the Jacques cell; if such were available it would be recognized that the cell is purely chemical. (Sci. Abs. 2:701, 1899)

1815
Reed, C. J. THERMOELECTRIC BATTERY. Am. Inst. Elec. Engrs. Trans. 15:291-325, 1898.

The author reproduces and discusses a number of results obtained by Liebenow and Strasser with cells containing fused alkali as the electrolyte. He claims that these results support a thermoelectric theory and not a chemical theory as supposed by their authors. In the subsequent discussion, Steinmetz contended that the emf might be directly due to chemical action owing to the variation of chemical affinity with temperature, although indirectly due to the external heat supplied. (Sci. Abs. 2:309, 1899)

1816
Richardson, O. W. ON THE ELECTRON THEORY OF CONTACT

ELECTROMOTIVE FORCE AND THERMOELECTRICITY. Phil. Mag. 23:263-278, Feb. 1912.

Abstract of a paper with this title presented at the New York meeting of the Physical Society, Oct. 14, 1911, appears in Phys. Rev. 33: 448-449, Nov. 1911.

A method is presented of deducing certain formulae which connect some of the physical properties of conductors, particularly in the domain of thermoelectricity, with the number and state of the free electrons present in them.

1817
Seymour, P. W. THE INFLUENCE OF THERMOELECTRIC EFFECTS ON THE MAXIMUM TEMPERATURE IN A RADIALLY CONSTRICTED GAS DISCHARGE BETWEEN ELECTRODES. Australian J. Phys. 14:279-294, figs., June 1961.

The analysis is generalized to include thermoelectric effects, and carried through for strictly longitudinal flow, for which at every point within the discharge the heat flux vector q and the current density vector j are parallel to the magnetic field H.

1818
Shockley Transistor Corp., Palo Alto, Calif. RESEARCH ON SEMICONDUCTOR TRANSPORT, by K. Hubner. 53p., Feb. 1, 1961. (Contract Nonr-2934(00))

The electrical coupling by phonons of two isolated layers as a method of studying the propagation properties of phonons in single crystal silicon at 77° K.

1819
Ure, R. W., Jr. SEMICONDUCTORS AND SEMI-METALS. In Heikes, R. R. and Ure, R. W., Jr., eds. Thermoelectricity: Science and Engineering, p.19-74, New York, Interscience Publishers, 1961.

Discussed in this chapter are electron energy levels, electron distribution, particle treatment of transport properties, distribution treatment of transport properties, and electron scattering mechanisms.

1820
Verschaffelt, J. LA THERMOMECANIQUE DE LA THERMOELECTRICITE. (THE THERMODYNAMICS OF THERMOELECTRICITY). Acad. Roy. Belg. Class. Sci. Bull. 36:26-46, 1960.

In French. Reviews and criticizes Kelvin's theory. In an analysis of a thermojunction of two alloys, inconsistencies in both Kelvin's and Meisner's theories are pointed out.

1821
Zemel, J. N. SURFACE DEPENDENCE OF THE THERMOELECTRIC POWER IN GERMANIUM AT ROOM TEMPERATURE: EXPERIMENTAL. Am. Phys. Soc. Bull. 6:27, Feb. 1, 1961.

Abstract only of paper given at the 1961 annual meeting of the American Physical Society, New York, February 1-4, 1961.

"A series of experiments have been conducted to determine the dependence of thermoelectric power on the excess charge in the surface space charge region in the room temperature range. The experiments were carried out on a thin sample of very pure intrinsic germanium, and gas ambients were used to vary the surface space charge. Extreme care was taken to reduce or eliminate spurious thermal gradients in the apparatus. The reproducibility of the data indicated that the apparatus was adequate. The temperature at which measurements were carried out were from 15° C to 35° C. A 1.5° C temperature difference was used to produce the thermal emf. Comparison of the experimental results with the theoretical predictions of Greene gave remarkably good agreement. Unfortunately, the role of the surface scattering mechanism in the experimentally achievable range of surface potential increments was not great enough to provide a clear proof of the scattering's

existence, let alone its magnitude. At lower temperatures, the surface thermoelectric power may have some interesting applications to the study of phonon scattering at surfaces." Entire item quoted.

C. Related Phenomena

1822
Bross, H. and Seeger, A. ELECTRON THEORETICAL INVESTIGATION OF DEFECTS IN METALS. V: GENERAL THEORY OF THE EFFECTS OF LATTICE DEFECTS ON THE TRANSPORT PROCESSES IN METALS. J. Phys. Chem. 4:161-176, 1958.

In German. The present paper treats the application of the Kohler-Enskog variational principle to the scattering of conduction electrons by lattice defects in as general a way as seems possible. Particular emphasis is laid on those cases (which at present cannot be dealt with by other methods) in which the relaxation time tensor has more than one essential component. The technique allows one to calculate the electrical and thermal residual resistivity at low temperature, and the electrical resistivity, thermal resistivity and thermoelectric power due to defects at temperatures above the Debye-temperature. Deviations from Matthiessen's rule and the connection with the anisotropy of the scattering centers are discussed in detail. (Astron. Info. Lit. Search 294:695, Dec. 1960)

1823
Chatterjee, G. P. STUDIES ON THERMOELECTRIC PHENOMENA IN RELATION TO STRUCTURAL CHANGES IN METALS AND ALLOYS. Indian Inst. Metals. Trans. 13:315-322, figs., Dec. 1960.

An attempt has been made in this paper to show that thermoelectric behavior, viz., changes in the thermoelectric characteristics, could be utilized as a powerful tool of research to throw more light on some of the phenomena occurring in solid metals and alloys.

1824
Gertsriken, S. D. and Novikov, N. N. THE STUDY OF TEMPERING AND FORMATION OF VACANCIES BY A METHOD OF THE THERMAL EMF IN Ag AND Pt. Fiz. Metal. i Metalloved 9:224-235, Feb. 1960.

In Russian. Trans. in Phys. Metals & Metallog. 9:(2):54-64, 1960.

In this work a new method is used to determine the activation energy of the movement formation of vacancies by the thermoelectric force generated in a thermocouple consisting of an annealed metal and a metal quenched from a high temperature. The activation energies of the movement and formation of vacancies determined by this method are in silver equal to 19,200 ± 200 cal/mol and 23,200 ± cal/mol, respectively. For platinum these quantities are 30,000 ± 300 and 32,000 ± 1000 cal/mol, respectively. The data obtained in this work show that vacancy flows exist inside the specimen. It is most likely that dislocations serve as such flows.

1825
McClellan, W. THERMOELECTRIC BEHAVIOR OF NICKEL NITRATE. Phys. Rev. 17:255-266, Oct. 1903.

The author determines the difference of potential developed between two platinum electrodes immersed in separate beakers containing a solution of nickel nitrate and connected by a tube, the contents of one of the beakers being heated by an electric current while the other is kept cool.

The results are in all cases very irregular, though much less so for boiled solution. The effective vibrating electrodes is not clear, but for good results the electrodes must be arranged with nodes at the surface of the electrolyte. It is concluded that if the thermoelectric power amounts to anything, it is probably positive. (Sci. Abs. 7A:2790, 1904)

1826
Ohta, Tokio. THEORY OF SEEBECK EFFECT IN PLASTICALLY DEFORMED SEMICONDUCTORS. Phys. Soc. Japan. J. 16:1561-1564, figs., Aug. 1961.

The effects of the reduction of free electron density due to the dislocation-acceptors and the scattering due to the space charge around the dislocation on the thermoelectric power of n-type materials are theoretically investigated in the temperature covering from impurity-to-transition-range and compared with the experimental data for near intrinsic n-Ge in only the transition range of temperature. In the intrinsic range of temperature the scattering effect due to the lattice deformation around the dislocation is discussed and compared also with the experimental data.

1827
Shaffer, L. H. THERMOELECTRIC PHENOMENA IN ELECTRODIALYSIS SYSTEMS. Nature 191: 591-592, illus., Aug. 5, 1961.

Gives attention to the possible existence of heat fluxes in electrodialysis experiments.

1828
van Aubel, Edmond. HALL EFFECT AND THERMOELECTRIC POWER. Acad. Sci. Paris. Compt. Rend. 135:786-788, Nov. 10, 1902.

In French. This is an experimental investigation upon the theory of Ettingshausen and Nernst, that the Hall effect is connected with the thermoelectric power. The effect was studied for bismuth, for an alloy of antimony and bismuth, and for a mixture of bismuth and sulphate of bismuth. The results show that the Hall effect is most intense for the last, and is thrice that for pure bismuth. For the alloy it is double that for the pure metal. The conclusions of Ettingshausen and Nernst are confirmed. (Sci. Abs. 6:666, 1903)

D. Materials

1. Measurements

1829
Bauerle, J. E., Sutter, P. H., and Ure, R. W., Jr. MEASUREMENTS OF PROPERTIES OF THERMOELECTRIC MATERIALS. In Heikes, R. R. and Ure, R. W., Jr., eds. Thermoelectricity. Science and Engineering, p. 285-338, New York, Interscience Publishers, 1961.

The particular measurements discussed are the thermal conductivity, the Seebeck coefficient, the electrical resistivity, the maximum temperature difference, and the contact resistance.

1830
Birkholz, U. ZUR EXPERIMENTALLEN BESTIMMUNG DER THERMOELEKTRISCHEN EFFEKTIVITAET VON HALBLEITERN. (EXPERIMENTAL DETERMINATION OF THERMOELECTRIC EFFICIENCY OF SEMICONDUCTORS). Solid-State Electron. 1:34-38, Mar. 1960.

In German. Method by means of which absolute thermoelectric power, electric conductivity, and thermal conductivity are ascertainable at room temperature by use of single piece of apparatus. (Eng. Index p. 1501, 1960)

1831
Cadorette, J. W. EVALUATION OF THE RELIABILITY OF THERMAL CONDUCTIVITY DATA ON THERMOELECTRIC MATERIALS. In Navy Science Symposium, 5th, Annapolis, Md., 1961. Naval Research. Proceedings, vl. 1, p. 52-63, Washington, D.C., Office of Naval Research, Dept. of the Navy, 1961. (ONR-9, vl. 1)

The conclusion states: "From this study it is evident that thermal conductivity comparisons using the

Skinner Apparatus can be made with a high degree of precision. Reproducibility within laboratories and between laboratories is entirely adequate for development work in the thermoelectric field."

1832
Crawford, G. J. B. NOTE ON THE MEASUREMENT OF THE FIGURE OF MERIT OF THERMOELECTRIC MATERIALS AND OF REFRIGERATING JUNCTIONS. Rev. Sci. Instr. 32:353-354, Mar. 1961.

A rapid, reliable, and reasonably accurate (5%) determination of the thermoelectric figure of merit (Z) can be made without the use of a vacuum system. The method is described in this note.

1833
Glazov, V. M. and Krestovnikov, A. N. THERMOELECTRIC PROPERTIES OF MATERIALS IN MICROVOLUMES. Zavod. Labor. 27:416-419, 1961.

In Russian. By means of a needle probe combined with an optical system, the micro-thermoelectromotive force can be measured at various points of a metallographic preparation, i.e., both within the boundaries themselves. This way several metallurigical problems can be investigated, such as that of chemical interactions between components of a system. Thus, for the system Cu-Cr-Zr it was possible to show that maximum solubility of chromium and zirconium in copper corresponds to the quasi-binary section Cu-Cr_2Zr of the diagram. In this way the formation of the compound Cr_2Zr was established, confirmed by deviations of microhardness increments from the additivity rule. (Crerar Met. Abs. 2510, Jly. 1961)

1834
Kearns, D. R. ELECTRICAL PROPERTIES OF ORGANIC SOLIDS. Part IV. THERMOELECTRIC POWER. In California University. Radiation Laboratory, Bio-Organic Chemistry Quarterly Report for March, April, May 1960, p. 62-64. Berkeley, Calif., June 29, 1960. (Rept. 9208) (Contract W7405-eng-48)

The thermoelectric power measurement is a method used to determine the sign of the majority charge carrier in a semiconductor. Applications in determinations of the sign of the charge carrier in organic substances were investigated. (Nuclear Sci. Abs. 15:5937, 1961)

1835
Kristensen, I. K. EXPERIMENTAL INVESTIGATION OF TWO KELVIN RELATIONSHIPS. Fiz. Tverdogo Tela 2:2641-2642, Oct. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2356, Apr. 1961.

The apparatus is described on which measurements were made on three specimens of n-type germanium in a temperature range from -80 to 0° C. The Peltier coefficient and the thermal emf were measured with an accuracy of 2%.

1836
McConnell. G. and Sehr, R. MEASUREMENT OF THE ELECTRICAL RESISTANCE OF METAL-THERMOELECTRIC SEMICONDUCTOR CONTACTS. Solid-State Electron. 2:157-164, Mar. 1961.

Small contact resistance in thermoelectric junctions relative to the volume resistance is an important factor in the efficiency of the thermoelectric element. A systematic study of different bonding techniques requires a sensitive measuring method. Several methods are discussed and a four-terminal bridge method is described in detail. This method allows measurement of contact resistances of the order of 1 $\mu\Omega$ with an accuracy of ±5%. Measurements on nickel-plated and unplated soldered junctions of doped Bi_2Te_3 with copper having a constant resistance of 10 $\mu\Omega$ showed no rectification, but a variation of almost 100% in contact resistance around the periphery of the junction.

1837
Mooser, B. and Woods, S. THERMOELECTRIC POWER OF GERMANIUM AT LOW TEMPERATURES. Phys. Rev. 97:1721-1722, Mar. 15, 1955.

Measurements made on Ge over the temperature range from 20 to 300° K are reported. The electron diffusion and phonon drag components of thermoelectric power are considered.

1838
U.S. Naval Research Laboratory, Washington, D.C. EXPERIMENTAL STUDY OF THERMOELECTRIC THEORY, by Daniel Friedman. 14p., figs., Jan. 1961. (Memo. Rept. 1138)

The design and performance of a unit which can be used to provide an experimental verification of thermoelectric theory and/or to measure the thermoelectric properties of materials is described. Using doped Bismuth Telluride p- and n-type materials (at approximately room temperature), the following results were obtained. The electrical resistance of p- and n-type thermoelectric material measured by d-c and a-c methods were identical within the limits of experimental error. The predicted performance of the thermoelectric unit showed good agreement with the experimentally measured performance. Some of the effects of high contact resistance are discussed and recommendations for additional research outlined.

1839
Watson, H. L. and Abrams, H. THERMOELECTRIC MEASUREMENTS OF TEMPERATURES ABOVE 1500° C. Am. Electrochem. Soc. Trans. 54:19-36, 1928.

After a brief discussion of the standard methods of temperature measurement from 1000 to 2000° C, an account is given of a tungsten-graphite thermocouple, including its construction, characteristics and application. This couple has been used, with suitable protection, to over 1700° C in oxidizing atmospheres. The elements when properly selected and treated are interchangeable within 5% and an expression has been obtained for the temperature-emf relation over the useful range. Automatic recording and control of furnace temperatures in ceramics and steel making have been made possible by use of this couple.

2. Properties

1840
Arizona State University, Tempe, Ariz. THERMOELECTRIC MATERIALS AND DEVICE RESEARCH. 3 issues, Feb., May, Aug., 1961. (Quart. Prog. Repts. 5, 6, 7) (Contract DA 36-039-sc-85249)

The material under current investigation is rutile. Methods of preparing sintered rutile containing colloidal sols of tungsten and tantalum metal are being studied. Furthermore, the electrical properties of the barrier at a rutile-metal interface are being studied in order to find suitable metals for the colloidal phase.

1841
Arvin, M. J. THERMOELECTRIC EFFECTS IN MOLYBDENUM DISILICIDE. J. Appl. Phys. 24:498, Apr. 1953.

Letter. Further evidence for the metallic nature of $MoSi_2$ is given; in particular, its thermal emf against Pt, in the temperature range -60 to 600° C, is much the same as that for Cu against Pt.

1842
Baranskii, P. I. and Tomkevich, S. L. THE BRIDGMAN EFFECT IN BISMUTH TELLURIDE CRYSTALS. Fiz. Tverdogo Tela 2:1714-1722, Aug. 1960.

In Russian. Trans. in Soviet Phys. Solid-State 2:1551-1557, Feb. 1961.

Semiconductor materials exhibiting high values of the differential thermal emf and electrical conductivity

at low values of the heat conductivity are best suited for the direct conversion of heat energy into electric energy and also for the conversion of electric energy to produce high temperatures or low temperatures in refrigeration. Bismuth telluride was found to be a semiconductor which satisfied these requirements rather well.

1843
Battelle Memorial Institute, Columbus, Ohio. INDIUM ANTIMONIDE FOR SEMICONDUCTOR DEVICE FEASIBILITY STUDIES, by T. S. Shilliday, F. J. Reid, et al. 2 issues, Jan., Apr. 1961. (Sci. Repts. 5,6) (Contract AF33(616)-6450)

Work reported on includes bulk material investigation, InSb galvanomagnetic devices, thin films of InSb, and p-n junction studies.

1844
Battelle Memorial Institute, Columbus, Ohio. THERMOELECTRIC POWER GENERATION AND RELATED PHENOMENA. 30p., Mar. 24, 1961. (Bimon. Prog. Rept. 12) (Contract Nobs-77034) (AD 258 988)

An alloy of 85 GaAs-15 AlAs was prepared by zone leveling at a slow crystallization rate, and an initial effort to prepare a GaSb-GaP alloy was undertaken. Also, high-temperature electrical measurements were made on a GaAs-AlAs alloy and on a selected sample of GaSb. Theoretical work on the electronic properties of GaAs and GaAs-AlAs based on the assumption of secondary minima in the conduction band has been carried out and the predictions of theory compared with experimental results.

1845
Battelle Memorial Institute, Columbus, Ohio. THERMOELECTRIC POWER GENERATION AND RELATED PHENOMENA. Final Report, April 24, 1959 - March 7, 1961. 46p., May 15, 1961.

Work on materials was directed toward: (1) preparation of homogeneous alloys of GaAs-AlAs; and (2) the development of an apparatus suitable for high-temperature electrical measurements under a controlled atmosphere. Many such alloys were prepared and their properties studied by electrical, optical, and chemical means, as well as by X-ray diffraction and electron-probe analysis. The apparatus was designed to successfully operate at temperatures up to 740° C.

A section is included on the general theory of transport properties of semiconducting materials having subsidiary conduction-band minima from the center of the Brillouin zone.

A brief resumé of the role of irreversible thermodynamics in the determination of transport coefficients is included.

1846
Belloc, G. THERMOELECTRIC POWER OF STEELS AND NICKEL-STEELS. Acad. Sci. Paris. Compt. Rend. 134:105-106, Jan. 13, 1902.

In French. This is a continuation of previous work on soft iron and steel, with an extension to nickel-steels containing from 5 to 35.5% of nickel. The result is that the (dE/dt, t) curve has a minimum about 380°, a maximum between 660° and 870°, depending on the composition, and another minimum about 120° above the maximum. (Sci. Abs. 5:876, 1902)

1847
Bennett, L. C. and Wiese, J. R. EFFECTS OF DOPING ADDITIONS ON THE THERMOELECTRIC PROPERTIES OF THE INTRINSIC SEMICONDUCTOR $Bi_2Te_{2.1}$-$Se_{0.9}$. J. Appl. Phys. 32:562-564, figs., Apr. 1961.

An alloy of 70 mol % Bi_2Te_3-30 mol % Bi_2Se_3, or $Bi_2Te_{2.1}Se_{0.9}$, is the intrinsic semiconductor of the pseudobinary system Bi_2Te_3-Bi_2Se_3. This V-VI alloy was doped with lead (Group IV) and iodine (Group VII) separately and together. The effects of the dopants are analogous to those

produced by Group III or Group V impurities in Group IV elemental semiconductors, the lower Group impurity producing a p- type material and the higher Group impurity an n- type material. Plots of the Seebeck coefficient, electrical conductivity, and thermal conductivity are given as a function of impurity concentration and show that the separate effects of the impurities are countered when the impurities are in the lattice together in the same amount.

Doping was also done with silver and iodine, separately and together. The results indicate that the silver is in the lattice interstitially (lead and iodine substitutionally) and that the type material produced is dependent also on how the impurity atom enters the lattice.

1848
Bridgman, P. W. THERMAL CONDUCTIVITY AND THERMOELECTROMOTIVE FORCE OF SINGLE METAL CRYSTALS. Nat. Acad. Sci. Proc. 11:608, 1925; 10:411, 1924.

The thermal conductivity at room temperature and the thermal emf in the range between room temperature and 100° C is measured as a function of direction for single crystal rods of Bi, Zn, Cd and Sn.

1849
Buchanan, J. ON THE THERMOELECTRIC POSITION OF CARBON. Phil. Mag. 20:117-125, 1885.

An experiment is described in which keeping carbon at a moderately high temperature altered the molecular condition of this material, the alteration being manifested as a change in the thermoelectric power of the carbon.

1850
Busch, G. and Steigmeier, E. THERMAL CONDUCTIVITY, ELECTRICAL CONDUCTIVITY, HALL EFFECT, AND THERMOELECTRIC POWER OF InSb. Helv. Phys. Acta 34:1-28, figs., Feb. 15, 1961.

In German. The thermal conductivity, electrical conductivity, Hall coefficient, and thermoelectric power of single crystals of InSb have been measured between 195 and 715°K.

1851
Christy, R. W. THERMOELECTRIC POWER OF SILVER HALIDES. J. Chem. Phys. 34:1148-1155, Apr. 1961.

Thermoelectric power measurements were made on the systems AgCl + $CdCl_2$, AgBr + Ag_2S, and AgBr + CdS, as well as the pure silver halides, in the temperature range from 100° to 400° C. Silver metal electrodes were used. The behavior of AgCl and $CdCl_2$ is similar to the previously investigated AgBr + $CdBr_2$ system, except that the effect of the impurity is more pronounced in AgCl. The results of Cd doping of AgBr and AgCl are analyzed according to the theory of Howard and Lidiard to give the concentration of Frenkel defects. the ratio of mobilities, and the quantities $Q^* + q^*$, $q^* + Ts'$, and $q^* + Ts$; where q^* and s' are the heats of transport and entropies of formation for the interstitials and vacancies. The results are in agreement with conductivity data, but the heats of transport are surprisingly large and temperature dependent. It is concluded that association between Cd^{++} and Ag^+ vacancies is negligible above 100° C, but that association between S^{--} and Ag^+ interstitials, and between Cd^{++} and S^{--}, is significant even at 400° C. (Sci. Abs. 64B:6185, 1961)

Also issued as Dartmouth College Tech. Rept. 1, (Contract Nonr-279900)

1852
Chrysler Corp. Engineering Div., Detroit, Mich. RESEARCH PROGRAM ON SEMICONDUCTING COMPOUNDS FOR THERMOELECTRIC POWER GENERATION AT HIGH TEMPERATURES. 3 issues, Jan., Mar., May 1961. (Bimon. Prog. Repts. 4, 5, 6) (Contract Nobs-78664) (AD-259 038, AD259 104)

This program covers the investigation of semiconducting combinations of the heavy refractory metals with high atomic weight elements of groups IV B, V B, and VI B of the periodic table, and of less metallic variations of the refractory superlattice intermetallic compounds, as possible materials for high temperature thermoelectric elements.

1853
Conference on Silicon Carbide, Boston, 1959. PROCEEDINGS. SILICON CARBIDE. A HIGH TEMPERATURE SEMICONDUCTOR, ed. by J. R. O'Connor and J. Smiltens. 521p., illus., New York, Pergamon Press, 1960.

Use of silicon carbide as a thermoelectric generator is evaluated, among other uses.

1854
Cosgrove, G. J., McHugh, J. P., and Tiller, W. A. EFFECT OF FREEZING CONDITIONS ON THE THERMOELECTRIC PROPERTIES OF $BiSbTe_3$ CRYSTALS. J. Appl. Phys. 32:621-623, Apr. 1961.

The thermoelectric parameters α, $1/p$, and $1/(K-K_e)$ of oriented polycrystals increase as the freezing rate decreases and as the temperature gradient in the liquid at the interface increases. The effects are primarily attributed to the variation in the degree of microsegregation produced in the crystals as a function of the freezing conditions.

1855
Darling, A. S. THERMOELECTRIC PROPERTIES OF RHODIUM-PLATINUM ALLOYS. Instr. & Contr. Sys. 34:861-862, May 1961.

A review of the thermoelectric properties and behavior of rhodium-platinum alloys of various composition.

1856
Dewald, J. F. and Lepoutre, G. THERMOELECTRIC PROPERTIES OF METAL-NH_3 SOLUTIONS. III. THEORY AND INTERPRETATION OF RESULTS. Am. Chem. Soc. J. 78:2956-2962, Jly. 5, 1956.

The effects of electron-electron and electron-ion interactions in the thermodynamic equations derived for thermoelectric power of metal-NH_3 solutions are discussed in considerable detail. A large negative heat of transport of the electrons in these solutions is shown to be the cause for anomalies in thermoelectric behavior. This in turn is attributed to the fact that electrons move through solutions even at high dilution, by a quantum tunnel process, rather than ionic or conduction band means.

1857
Dudkin, L. D. and Abrikosov, N. Kh. THERMOELECTRIC PROPERTIES OF COBALT ANTIMONIDES. Voprosy Met. i Fiz. Poluprovodnikov (Moscow, Akad. Nauk. SSSR) Sbornik 1957, p. 97-109.

In Russian. Abs. in Chem. Abs. 55:8058, 1961.

1858
Dupuy, E. L. and Portevin, A. M. THE THERMOELECTRIC PROPERTIES OF SPECIAL STEELS. Iron & Steel Inst. J. 91:306-335, 1915.

The study of the thermoelectric force within two given temperature ranges -80° C to 0° C and 0° C to 100° C have been taken into consideration.

1859
Electro-Optical Systems, Inc., Pasadena, Calif. HIGH TEMPERATURE SEMICONDUCTING COMPOUNDS FOR THERMOELECTRIC POWER GENERATION. 4p., Apr. 30, 1961. (Rept. 1592-2M-2) (Bimon. Prog. Rept. 2) (Contract Nobs-84327)

Reports installation of the apparatus for measurement of thermal conductivity, electrical conductivity, and Seebeck effect of the following materials-thorium, thorium oxide, uranium, uranium oxide, hydrogen

sulfide, selenium, tellurium, and sulfur.

1860
Erez, G. and Rudman, P. S. LONG-RANGE ORDER IN Fe-Al ALLOYS. II. THERMOELECTRIC POWER. Phys. & Chem. Solids 18:307-315, figs., Mar. 1961.

The thermoelectric power, TEP, relative to copper has been measured in Fe-Al alloys: (a) for the alloy 25.05 at. % Al over the temperature range 100-905° C; (b) at room temperature over the composition range 17.0-28.5 at. % Al as a function of quenching temperature. The critical temperature for the Fe_3Al structure was marked by a sharp change in the slope of the TEP vs. temperature plot and the phase boundary was accordingly determined; for stoichiometric Fe_3Al, $T_c = 560 \pm 5°$ C. The critical temperature of the FeAl structure was not marked by a similar change in slope; however, a change in slope of the TEP vs composition plot defines this transformation. Fe_3Al order acts to increase while FeAl order acts to decrease the TEP. The results are interpreted in terms of distortion of the density of states curve of the 4s band due to the formation of new Brillouin zones accompanying ordering. The results are discussed in terms of the change on ordering of the kinetic energy of the 4s electrons as being the origin of the ordering energy for the Fe_3Al.

1861
Fedash, G. M. and Surovova, V. I. INVESTIGATION OF THE THERMOELECTROMOTIVE FORCE GENERATED IN A CIRCUIT [FORMED BY] DEFORMED AND UNDEFORMED REGIONS OF A METAL. Fiz. Met. i Metalloved. 10:20-23, Jly. 1960.

In Russian. Trans. in Phys. of Metals & Metallog. 10(1): 21-24, 1960.

The effect of various factors on thermo-emf, E, generated between deformed and undeformed Zn, was studied. In the case of polycrystalline specimens, E was negative and increased with increasing degree of deformation and decreasing initial grain size. E generated in single crystals was positive, its magnitude depending not only on the degree of deformation, but also on the relative orientation of the basal planes in the deformed and undeformed parts of the specimen. With the exception of junctions formed by two single crystals with differently oriented basal planes, junctions formed by deformed and undeformed Zn not only did not lose their ability to generate E after repeated heating, but the nagnitude of E increased as a result of this treatment until a certain maximum value was reached. E was also generated between the coarsely- and finely-grained crystalline regions of otherwise homogeneous specimens.

1862
Fein, A. E. RADIATION EFFECT. In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity; Science and Engineering, p. 120-153, New York, Interscience Publishers, 1961.

A prediction is made of the general behavior of thermoelectric materials under irradiation. This is done by extrapolating the information discussed regarding effects of radiation on metals, semiconductors, alkali halides, insulators, and organic compounds.

1863
Feltin'sh, I. PROPERTIES OF ARSENOSELENIDES OF GALLIUM AT HIGH TEMPERATURES. Latv. PSR Zinat. Akad. Vestis (USSR) no. 9:73-78, 1960.

In Russian. Results are presented of a study of the Hall and thermoelectric effects in solid solutions of the system $GaAs-Ga_2Se_3$ in the temperature range 500-1000° K. The number and mobility of current carriers are calculated where they are determined principally by one type of carrier (electrons or holes).

It was found that the law of dissipation of current carriers is modified according to the composition of samples. In substances with many structural defects, a sharp decrease of mobility starts at a certain temperature and continues with further rise of temperature. (Sci. Abs. 64A:3766, 1961)

1864
Fischer, W. A. and Lorenz, G. SEMICONDUCTIVITY OF CHROMIUM OXIDE. In International Conference on Solid State Physics, Electronics, and Telecommunications, Proceedings, Brussels, 1958, vl. 4 (Part 2), p. 955-963, New York, Academic Press, 1960.

The resistivity and thermoelectric power of Cr_2O_3 changes from a temperature-independent region below 1250° to a strongly temperature-dependent region at higher temperatures. The values in both regions are independent of the O pressure. The thermoelectric power shows that Cr_2O_3 is p-type, but changes to n-type when TiO_2 is added. The addition of TiO_2 or Cu_2 makes the thermoelectric power sensitive to O_2 pressure. The Cu or Ti atoms occupy Cr vacancies and release holes and electrons, respectively. The energy gap was 1.9 e.v. in the intrinsic region.

1865
France. Compagnie Generale de Telegraphie San Fil, Puteaux, Seine. A PREPARATION AND STUDY OF COMPOUNDS OF THE II-IV TYPE AND MIXTURES THEREOF TO DETERMINE THEIR USEFUL SEMICONDUCTING PROPERTIES. 20p., illus., Sept. 30, 1959. (Quart. Tech. Status Rept. 2) (Contract AF61(052)243) (AD-229 661)

Crystals were prepared with compositions which covered the entire range of $Mg_2Sn_xPb_{1-x}$, where x is 0 to 1. Zone melting on the compounds continued under 5 kg/sq cm pressure of Ar and single crystals of reasonable size were obtained. The phase diagram of the mixture $Mg_2Sn_xPb_{1-x}$ was investigated by a thermo-differential analysis method. Mg_2Sn and Mg_2Pb were miscible in any proportion. A review is made of the methods of measuring thermoelectric power (α) and thermal conductivity (κ).

1866
France. Compagnie Generale de Telegraphie sans Fil, Puteaux, Seine. A PREPARATION AND STUDY OF COMPOUNDS OF THE II-IV TYPE AND MIXTURES THEREOF TO DETERMINE THEIR USEFUL SEMICONDUCTING PROPERTIES, by H. Guennoc. 10p., 1959 (Quart. Tech. Status Rept. 3) (Rept. 1321) (AD-236 763)

Measurements of resistivity and Hall effect as a function of temperature were made on Mg_2Sn; they show that crystals obtained by fission under a pressure of 50 kg/sq cm contain about 10^{17}/cc electrically active carriers; after purification by the zone refining process, the number of carriers is of the order of 10^{16}/cc, all the crystals being n-type. The speed of zone displacement and the thermal gradient in the neighborhood of the melted zone appear to be more important parameters than the number of passes in the zone.

1867
France. Compagnie Generale de Telegraphie San Fil, Puteaux, Seine. PREPARATION AND PROPERTIES OF THERMOELECTRIC MATERIALS. 7p., Apr. 30, 1961. (Rept. 3) (Contract DA 91-591-EUC-1505) (AD 257 395)

The preparation of molybdenum telluride - $MoTe_2$ - is described, as well as for $MoSe_2$, WSe_2, and WTe_2.

1868
Franklin Institute. Laboratories for Research and Development, Philadelphia, Pa. RESEARCH IN THERMOELECTRICITY, by C. A. Domenicali. 6 issues, Oct. 1952, Jan., Apr. 1953, Jan., Apr., Jly. 1954. (Repts. P-2292-3, -4, -5,

-7, -9, -10) (Contract DA36-039-SC-15460) (AD-4477, AD-5400, AD-16 361, AD-25 427, AD-33 451, AD-47 258)

Progress is summarized concerning the correlating of the thermoelectric properties of metals, alloys and semiconductors with the electronic and crystal structures of these materials.

1869
General Atomic, John Jay Hopkins Laboratory for Pure and Applied Science, San Diego, Calif. HIGH-TEMPERATURE BROAD-BAND SEMICONDUCTORS, by S. W. Kurnick, M. F. Merriam, and G. L. Guthrie. 9p., illus., Jan. 6, 1961. (Rept. GACD 1921) (Quart. Tech. Summary Report. 1) (Contract Nobs-77144) (AD-259 034)

Fundamental work was continued on cerium sulfide, Ce-S, in a continuing attempt to better understand the electrical and thermal transport mechanism in this semiconductor and others having the Th_3P_4 structure. Work was started on synthesis and evaluation of related compounds which may show promise as high temperature thermoelectric materials. Results so far indicate that qualitatively different transport mechanisms are dominant in different composition ranges. From a practical standpoint, measurements to data have yielded zT's as high as 0.33. This places CeS in the role of a leading high temperature thermoelectric candidate.

1870
General Atomic. John Jay Hopkins Laboratory for Pure and Applied Science, San Diego, Calif. HIGH-TEMPERATURE BROADBAND SEMICONDUCTORS. 20p., Apr. 10, 1961. (Rept. GACD 2165) (Quart. Tech. Summary Rept. 2) (Contract Nobs-77144)

Work is reported on Ce-S compounds (chemistry of doped Ce-S, thermal expansion measurements, Hall coefficient measurements, lattice parameter studies, high-performance n-type Ce-S, single-crystal preparation, index of refraction) on sulfides of La, Pr, and Gd (concentration gradients, contact experiments, and results of electrical measurements).

1871
General Electric Co., Cincinnati, Ohio. THERMOELECTRIC STABILITY TESTS. 31p., Aug. 1961. (Rept. APEX-746) (Contract AF33 (600)38062)

Tests were conducted at 2000°, 2200°, 2400°, 2600°, and 2800° F. Decalibrations were seen to increase with increasing temperature. Flame-sprayed bare wire and the Duax configuration show indications of very favorable stability. There are indications that the less pure, more economical, and more readily applied alumina for flame-spray work provides thermoelectric stability as good as, or better than, the high purity materials.

1872
General Electric Co. Aircraft Accessory Turbine Div., Syracuse, N. Y. MATERIALS RESEARCH AND DEVELOPMENT FOR THERMOELECTRIC POWER GENERATION. 8 issues, 1961. (Prog. Repts. 7 through 14) (Contract DA44-177-TC-639)

Progress of experimental investigations on $CuGaTe_2$ is reported.

1873
General Electric Co. Knolls Atomic Power Laboratory, Schenectady, N. Y. ANNEALING OF REACTOR RADIATION DAMAGE IN LEAD AND BISMUTH TELLURIDES. 66p., Jly. 3, 1961. (KAPL-2159)

Semiconductor materials of interest for thermoelectricity applications are purposely heavily doped to carrier concentrations which tend to lie in the range 10^{19} cm^{-3}. The characteristic suggests that these materials may tend to be more resistant to the effects of irradiation than are the lightly doped semiconductors. These general statements have been borne out in the work reported.

1874
General Electric Co. Knolls Atomic Power Plant, Schenectady, N. Y. REACTOR TECHNOLOGY REPORT NO. 12 - METALLURGY. v.p., Mar. 1960. (KAPL 2000-9)

Stability of Lead and Bismuth Tellurides on Pulse Heating to Successively Higher Temperatures, by M. Balicki and F. K. Heumann, p. A. 19-A. 36.

Thermal shock tests on thermoelectric materials to determine resistance to thermal cycling, prolonged exposure to high-temperature gradients and rapid heating and cooling rates. P-type and n-type conductivity PbTe and Bi_2Te_3 samples are induction-heated and water quenched in successive cycles with increasing temperature rise to within 100° C of their respective melting points. Data for thermal stress-strain relations and fracture mechanisms. (Rev. Met. Lit. 17:53, Aug. 1960)

1875
General Mills, Inc. Mechanical Division, Minneapolis, Minn. INVESTIGATIONS OF BISMUTH-TELLURIUM-SULFUR COMPOUNDS. Final Report, by H. H. Soonpaa and R. K. Mueller. 76p., May 15, 1961. (Rept. 2195) (Contract Nonr-1589(14))

A new semiconducting crystalline compound - $Bi_2Te_7S_5$, or genilide - has been prepared. Indications are that with an improved coefficient it might be a good thermoelectric material.

1876
Glascock, H. H., Jr. THERMOELECTRIC AND OPTICAL PROPERTIES OF CALCIUM OXIDE. Dissertation Abs. 22:298, 1961.

Abstract only of PhD thesis, University of Missouri, 1961.

The specific electrical conductivity and thermoelectric power of sprayed aggregates of calcium oxide were measured, as a function of temperature, for several states of activation and were found to exhibit the characteristics of a pore conductor. The typical break in the conductivity curve occurred at about 900° K in well activated samples. From this temperature, and an estimate of the mobility of an electron in calcium oxide, the electron affinity of calcium oxide is estimated to be .7 ev.

The opacities of thin backed films of calcium oxide were measured at room temperature over the energy range 5.5 to 11.3 ev. At energies below 6 ev the opacity was low. A sharp peak, attributed to the formation of excitons, was observed at about 7.1 ev. Two other strong maxima occurred near 8.3 and 10.0 ev. Maxima may also exist around 9.3 and 11.0 ev. The width of the forbidden band of calcium oxide is estimated to be near 7.7 ev.

1877
Gol'dberg, A. I. and Gel'd, P. V. THE EFFECT OF IMPURITIES ON THE THERMOELECTRIC PROPERTIES OF LOW-TEMPERATURE LEBOITE. Trudy Ural Politekh. Inst. im S. M. Kirova no. 96:190-194, 1960.

In Russian. Abs. in Chem. Abs. 55:16361, 1961.

1878
Gruneisen, E. and Erfling, H. D. THERMOKRAFT REINER BERYLLIUMKRISTALLE UND IHRE ANDERUNG IN TRANSVERSALEN MAGNETFELD. (THERMOELECTRIC POWER OF PURE Be CRYSTAL AND ITS VARIATION IN A TRANSVERSE MAGNETIC FIELD). Ann. Physik 36:357-367, Oct. 1939.

In German. The thermoelectric power of a Be crystal was measured in a transverse magnetic field. Variation with the magnitude and direction of the field and the temperature was determined. Fields up to 12,000 oersteds and temperatures down to -250° C were used.

With no magnetic field the thermoelectric power of Be rises rapidly with the temperature to a value of about 14 at room temperature.

1879
Harrison, E. P. THERMOELECTRIC FORCE OF NICKEL, COPPER, AND IRON. Phil. Mag. 3:177-195, Feb. 1902.

Two accumulators send current through 1,000 ohms and then a potentiometer wire, the thermocouple balancing on the latter. A cadmium cell is the standard emf. The Cu-Fe, Fe-Ni, and Ni-Cu were all investigated. Temperature was registered by the Callendar automatic recorder, the range being -- 180° to 1,050°. Special care was taken to avoid oxidation at high temperature by having an atmosphere of hydrogen. The Ni-Cu curve differs little from a straight line, and the Cu-Fe curve differs little from a parabola; the author gives equations to express these differences in each case. Curves and numerical tables are given for the thermoelectric forces and Peltier effect. A special set of measurements were made on the resistances of the three metals up to 1,000°. The author's results differ materially from those of Fleming and Dewar in most cases. One result is to show that the thermoelectric change in Ni-Cu coincides approximately with the resistance change. (Sci. Abs. 5:1099, 1902)

1880
HEAT TO ELECTRICITY - DIRECTLY. Georgia Tech. Engr. 21:48, Dec. 1959.

A brief account is given of "a new class of materials (thermoelectric materials) which can convert the heat of a burning fuel, or other high-temperature source of heat, directly into electricity."

1881
Heikes, R. R., Miller, R. C. and Ure, R. W., Jr. SURVEY OF KNOWN THERMOELECTRIC MATERIALS. In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity: Science and Engineering, p. 405-442, New York, Interscience Publishers, 1961.

Those materials which have a high figure of merit are discussed, viz. ZnSb, Pb(Te,Se), $(Bi,Sb)_2(Te,Se)_3$, In(Sb, As, P), MnTe, and (Ge, Bi)Te.

1882
Hollander, L. E., Jr. ELECTRICAL CONDUCTIVITY AND THERMOELECTRIC EFFECT IN SINGLE CRYSTAL TiC. J. Appl. Phys. 32:996-997, June 1961.

Monocrystals of TiC were cleaved from ingots grown by arc fusion, and cleavange planes were studied by x-ray and measured for resistivity. Resistivity has a positive temperature coefficient and is 200 μohm-cm in the (100) direction. Thermoelectric power is 7.8 μv/°C and indicates n-type conduction. No hydrostatic piezoresistivity was observed.

1883
Horner, P. THERMOELECTRIC POWER OF SINGLE CRYSTALS OF GALLIUM. Nature 191:58-59, fig., Jly. 1, 1961.

As part of a program to investigate the anisotropy of non-cubic crystals, the thermoelectric power of single crystals of the orthorhombic metal gallium has been examined. The aim of the program is the explanation of the large magnitude of the anisotropies of the physical properties of gallium.

1884
Igishev, V. N. and Gel'd, P. V. THERMOELECTRIC PROPERTIES OF ALLOYS OF THE Fe-FeSi SYSTEM. Trudy Ural Politekh. Inst. im S. M. Kirova no. 96:182-189, 1960.

In Russian. Abs. in Chem. Abs. 55:16360, 1961.

1885
Johnston, W. D. THE CHEMISTRY OF MIXED VALENCE MATERIALS

In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity; Science and Engineering, p. 232-284, New York, Interscience Publishers, 1961.

General chemical principles of mixed valence materials are developed, preparational techniques are discussed, and a few analytical techniques applicable to the field are described. The references cited have been chosen to illustrate the various principles and methods that may be generally applicable in the realm of thermoelectricity.

1886
King, R. E. J. and Bartlett, B. E. PROPERTIES AND APPLICATIONS OF INDIUM ANTIMONIDE. Phillips Tech. Rev. 22:217-225, figs., 1960/1961.

In this article the preparation of InSb crystals and the construction and performance of photocells based on InSb are described. Mention is also made of the use of InSb in Hall generators.

1887
Koe, S. THERMOELECTRIC EMF OF W-Hg AT HIGH TEMPERATURES. Czechoslov. J. Phys. 3:165, 1953.

The thermoelectric emf in millivolts is given as

$$2.006 \times 10^{-4} T^{1.723},$$

where T is the temperature in degrees C within the range 100 to 1500°.

1888
Koester, W. and Knorr, W. CHANGES IN PROPERTIES DURING THE HARDENING OF A COPPER CHROMIUM ALLOY. Z. Metallk. 45:350-356, 1954.

In German. Trans. no. TiL/T4800 available from Great Brit. Ministry of Supply, London.

The kinetic development of the separation process in a copper-chromium alloy with 0.6% Cr was followed by following the electrical conductivity, the thermoelectric power, the susceptibility and the hardness. Each property responds in a particular way to structural changes. There were no indications of cold-hardening. The energy of activation of the separation is 48000 cal/Mol. By investigating with X-rays it was possible in the case of the solution and separation of the chromium to establish a slight change in the lattice constant of the copper. No-X-ray indication could be obtained of the chromium separation. There appear to be no relationships in regard to orientation between separation and solid solution. Retrogression tests showed a re-solution of the heterogeneously separated chromium particles. The amount of retrogression increases approximately linearly with the retrogression temperature. It is smaller, the higher the age-hardening temperature and the longer the age-hardening period. There are quantitative deviations between the change in the conductivity and thermo-electric power which are to be attributed to the difference in the sensitivity of the two properties to the particle size.

1889
Konozenko, I. D. and Ust'yanov, V. I. ELECTRICAL PROPERTIES OF THE LEAD-ANTIMONY SYSTEM. Zhurn Tekh. Fiz. 27:1686-1694, 1957.

In Russian. Alloys containing 11, 12, 13, 14 and 37 wt. %, i.e., up to 50 atomic percent Sb, were investigated. Spectrographically pure Sb and Pb with < 0.00 percent Sn and Cu were used for the preparation of the experimental samples melted in evacuated glass ampoules. The electrical conductivity of all the studied alloys and their thermo-emf against Cu were measured at 0-300° C. The Hall effect and the sign and concentration of the current carriers were determined at room temperature only, with the exception of the 50 atomic percent Sb alloy in which the temperature dependence of the Hall effect was

studied at 0-300°C. The experimental results are shown in the form of graphs and are correlated with the constitution of Pb-Sb alloys. (Astron. Info. Lit. Search. 294:610, Dec. 1960)

1890
Kot, M. V. and Kretsu, I. V. ANISOTROPY OF SOME ELECTRICAL PROPERTIES OF ZINC ANTIMONIDE MONOCRYSTALS. Fiz. Tverdogo Tela 2:1250-1255, June 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:1134-1139, Dec. 1960.

The electrical conductivity, Hall effect and thermoelectric power were measured in three mutually perpendicular directions in single crystals of ZnSb between 100 and 500°K. They, as well as the hole mobility, were found to be different in the different directions. The width of the energy gap was deduced from the Hall effect to be 0.6 ev. (Sci. Abs. 63A:15967, Oct. 1960)

1891
Krogstad, R. S. and Moss, R. W. MAGNETIC FIELD DEPENDENCE OF THE LOW TEMPERATURE THERMOELECTRIC POWER IN N-TYPE SILICON. Am. Phys. Soc. Bull. 6:137, Mar. 20, 1961.

Abstract only of paper given at 1961 March meeting of the American Physical Society, Monterey, Calif.

"Measurements of the magnetic field dependence of the thermoelectric power in high-purity phosphorous-doped silicon will be reported. At temperatures above about 35° K, and with fields up to 24 k gauss, the thermoelectric power behaves in a normal manner with magnetic field. However, below this temperature the thermoelectric power has been observed to rise to a maximum, then decrease with increasing field. Indeed, for sufficiently low temperatures and high-field strengths, the differential thermoelectric power becomes negative. These results will be discussed in the light of a recent study by Appel, in which the deviation of both the electrons and phonons from equilibrium is taken into account." Entire item quoted.

1892
Krol', L. Ya., et al. THERMOCOUPLES FROM INTERMETALLIC COMPOUNDS ZnSb AND CdSb. Instr. Construction no. 8, p. 33-35, Aug. 1960.

Thermoelectric properties of semiconductor materials are discussed and apparatus for the measurement of relevant physical properties is described. (Instr. Abs. 16:2665, 1961)

1893
LATEST DEVELOPMENT IN DIRECT CONVERSION OF HEAT TO ELECTRICITY. Chem. Wk. 87:89, Sept. 10, 1960.

Bell Telephone Laboratories has developed a thermoelectric alloy made of Ag, Sb, and Te. This metal is expected to replace lead telluride and bismuth telluride, used in today's heat-to-electricity devices. Advantage: the alloy will enable more efficient thermoelectric equipment because of unusually good conductivity and electronic properties.

1894
Lockheed Aircraft Corp., Sunnyvale, Calif. A RAPID METHOD OF CRYSTAL GROWTH AND EVALUATION OF THERMOELECTRIC COMPOUND SEMICONDUCTORS, by V. J. King. 22p., illus., May 1961. (Rept. LMSD-325511) (AD-257 097)

Concurrent to providing material to the research and device groups of the Solid State organization during the past two years, a facility was developed which has the ability to produce, process, and evaluate compound semiconductor materials with a minimum expenditure of effort. The maximum value of this facility will probably be realized by intensified application to material problems, which require evaluation of large numbers of materials of diversified and unknown

behavior. Future work in the crystal laboratory is to be directed to the preparation and study of semiconductors of the multi-element compound and solid solution type, particularly for the purpose of locating more efficient thermoelectric materials. Specifically, the intentions are to extend the hand flame and associated techniques and the special thermal analysis method to establish the stoichiometry and behavior of the ternary compounds.

1895

L'vov, S. N., Nemchenko, V. F., and Samsonov, G. V. SOME REGULARITIES OF THE ELECTRICAL PROPERTIES OF THE BORIDES, CARBIDES, AND NITRIDES OF THE TRANSITION METALS OF GROUPS IV-VI OF THE PERIODIC SYSTEM. Akad. Nauk. SSSR. Dok. 135:577-580, Nov. 21, 1960.

In Russian. The Hall coefficient (R), resistivity (p), and thermoelectric power of many of the borides, carbides and nitrides of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, and W were measured. Several regularities were noted and it was deduced that the electron mobility in the group IV diborides is very much larger than in the corresponding metals. This is attributed to a reduction of electron scattering by the metal atoms and a broadening of the conductivity band. In the carbides only the latter process is effective while in the nitrides the d-band is broadened, causing increased hole mobility. During the transition from groups IV-V-VI, the hole contribution to the conductivity increases. It is concluded that the electron structure of both the metal and metalloid atoms have a large influence on the electrical properties of the compounds. (Sci. Abs. 64A: 3707, 1961)

1896

MacDonald, D. K. C., Pearson, W. B., and Templeton, I. M. THERMOELECTRICITY AT VERY LOW TEMPERATURES. Physica 24:S171, Sept. 1958.

Direct measurements have been made of the absolute thermoelectric power S of all the alkali metals between 2 and 20° K. These show considerable variety of behavior and the heavier metals, rubidium and caesium, are particularly anomalous. Current theoretical investigations by Bailyn and Ziman suggest that Umklapp-processes and "phonon-drag" effects may play a strong role. The work has been extended to temperatures below 1° K, and some results have been obtained on the noble metals as well as on the alkali metals. The noble metals, in particular, show a very large absolute thermoelectric power for which it seems very difficult to account on present theory.

1897

Massachusetts Institute of Technology, Cambridge, Mass. FIRST JOINT PROGRESS REPORT OF THE LABORATORIES FOR MOLECULAR SCIENCE AND MOLECULAR ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS, 219p., Jan. 1961. (Rept. NP-10158) (Contract Nonr-1841(10))

A semiannual report comprising descriptions of about fifty individual research efforts is presented. The majority of the work is done by graduate students. Investigations are included on materials for thermoelectrics. (Nuclear Sci. Abs. 15:19972, 1961)

1898

Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. MIGRATION AND EFFECTS OF COPPER IN p-TYPE BISMUTH TELLURIDE, by O. P. Manley. 35p., Sept. 1, 1960. (Tech. Rept. 376) (Contract DA 36-039-SC-78108)

The effects of copper on p-type Bi_2Te_3 were studied by examining the changes in resistivity and thermoelectric power induced in samples placed in intimate contact with copper.

1899
Matsushita, B. THE THERMOELECTRIC POWER OF LEAD SELENIDE SEMICONDUCTORS. Hiroshima Univ. Fac. Eng. Bull. 3:37-43, 1954.

Thermoelectric power of p-type (Se excess) PbSe of stoichiometric composition was expected to be positive at lower temperatures and negative at higher temperatures. However, single crystals are n-type and have negative thermoelectric powers up to 600° C. This thermoelectric power increases with increasing temperature. On the other hand, a crystal containing 2% Se as an impurity (p-type) gives a thermoelectric power of about 10^{-6} volts per degree at lower temperatures. In this case the thermoelectric power increases with temperature, reaching a maximum of approximately 3×10^{-4} volts per degree at room temperature and decreasing through zero (at about 300° C) to negative values. The general pattern is the same for a crystal containing 4% Se. Matsushita suggests intrinsic transition which excites the electrons up to the conduction band as an explanation of this behavior.

1900
Mee, C. H. B. ELECTRICAL CONDUCTIVITY AND THERMOELECTRIC POWER OF CALCIUM OXIDE. Nature 190:1093-1094, figs., June 17, 1961.

The work reported in this communication represents part of a program of research on calcium oxide, a component of some commercial mixed oxide coatings which has received but little attention.

1901
Merck Sharp and Dohme Research Laboratories, Rahway, N. J. STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS. 16p., Mar. 31, 1961. (Prog. Rept. 5) (Contract Nobs-78503)

This report describes a reexamination of the system (BiSbTeSe); it discusses some attempts to dope $AsBeTe_3$; and it describes the investigation of alloys of the chalcogenides of bismuth or antimony with mercury or cadmium chalcogenides. In addition, the attempted synthesis of In_4SbTe_3 is also described.

1902
Merck Sharp and Dohme Research Laboratories, Rahway, N. J. STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS. Summary Report 15p., May 31, 1961. (Contract Nobs-78503)

During the contract year, the principal research effort has been devoted to an intensive study of the alloy system bismuth-antimony-selenium-tellurium, in order to identify the composition having most useful thermoelectric properties. The majority of time was given to systems based on $Bi_2Te_3 \cdot 3Sb_2Te_3$, with brief surveys of the less interesting $Bi_2Te_3 \cdot 2Sb_2Te_3$ and $Bi_2Te_3 \cdot 7Sb_2Te_3$. Surveys have also been made on the n-type alloys $Bi_2Se_2Te_{3-x}$ and $AsBiTe_3$, and upon cadmium and mercury chalcogenide alloys with those of arsenic, antimony, and bismuth. Techniques have also been worked out for the evaluation of thermoelectric parameters.

1903
National Bureau of Standards, Washington, D. C. ELECTRICAL PROPERTIES OF NON-STOICHIOMETRIC SEMICONDUCTORS, by H. J. Becker and H. P. F. Frederikse. 30p., Sept. 1, 1961. (Rept. 7338)

The electrical conductivity σ, thermoelectric power Q, and Hall coefficient R are examined as a function of the ratio of hole-to-electron concentrations p/n for a non-degenerate semiconductor at constant temperature. From these relations the fundamental parameters of the material (forbidden band gap, mobilities and effective masses) can be derived.

1904
NEW CERAMICS CONVERT HEAT TO ELECTRICITY. Iron Age 182:125, Sept. 11, 1958.

In this very brief news article the mixed valence compounds of the transition metals are discussed. Ceramics made of nickel oxide, maganese oxide, and lithium-cobalt oxides are the first solid state thermoelectric materials capable of high temperature operation, an essential requirement of power generation materials.

1905
NEW THERMOELECTRIC MATERIALS FURTHER POSSIBILITIES OF DIRECT CONVERSION OF HEAT TO ELECTRICITY. Plant 18:60-61, Oct. 1958.

Information is taken from a speech made by Clarence Zener of Westinghouse.

1906
New York University. College of Engineering, New York, N. Y. MATERIALS FOR THERMOELECTRIC GENERATORS. Final Report, by E. Miller, F. Ermanis, and I. Cadoff. 10p., figs., Jly. 1961. (Contract AF19(604)3902)

The solidification and electronic characteristics of CdSb, ZnSb, and alloys of the Zn, Cd, Sb system were studied for application to thermoelectric devices.

1907
New York University. College of Engineering, New York, N. Y. A STUDY OF A CLASS OF INTERMETALLIC COMPOUNDS. THE CHALCOPYRITES. 5p., table, May 1959. (Quart. Prog. Rept. 9) (Contract AF33(616)3959) (AD-225 916)

The thermoelectric power (Seebeck coefficient S) of $CuInTe_2$, $AgInTe_2$, and $Au_{.25}In_{.25}Te_{.50}$ was measured by the differential method. The measurement covered a temperature range from -196° to +550° C. Data were tabulated at 8 temperatures from -150° to 500° C. $CuInTe_2$ showed a positive Seebeck coefficient within the entire investigated temperature range. $AgInTe_2$ had a fairly constant negative thermoelectric power of -110 μ V/°C from -160° C to room temperature. Above room temperature its value sharply decreased and reached zero at about 130° C. The annealing of $AgInTe_2$ ingots increased the thermoelectric power and shifted the transition to the intrinsic region to lower temperatures. $AuInTe_2$ alloy showed a very low Seebeck coefficient. It increased from -7.9 μ V/° C at -196.8° C to a maximum of 28.9 μ V/° C at -11° C. The Seebeck coefficient of $CuInTe_2$ was relatively high, being +150 -300 V/° C at room temperature and it increased at higher temperature. Its resistivity was relatively low, about 10^{-2} ohm-cm.

1908
New York University. College of Engineering, New York, N. Y. A STUDY OF A CLASS OF INTERMETALLIC COMPOUNDS, THE CHALCOPYRITES. 5p., table, Feb. 1950. (Quart. Prog. Rept. 12) (Contract AF33(616)3959) (AD-234 080)

Thermal conductivity, electrical resistivity, thermoelectric power, and figure of merit measurements were made on $CuInTe_2$ (I), $AgInTe_2$ (II), and $Ag_{25}Cu_{75}InTe_2$ (III) using the method of Putley and Harmon. The thermoelectric power and electrical resistivity of the compositions coincided with the values obtained previously by independent methods. The figure of merit for (I) was 0.265 and 0.310 x 10^{-3} at 0° and -79° C, respectively. These values were less than those for the best thermoelectric generators, but the region of stability for I lies in the 100° to 500° C range. The figure of merit was too small to be useful for practical applications.

The thermal conductivities of I and II at 0° C were 0.015 and 0.011 cal/sec-cm-° K, respectively. At -79° C, the thermal conductivity of I dropped to 0.0065 cal/sec-cm-° K. These values were lower than those of binary covalent semiconductors by a factor of 3 to 5, indicating a progressive decrease of thermal conductivity from elemental to binary to ternary covalent semiconductors. The thermal conductivity of III was decreased 5 times as compared to that of I, but its electrical resistivity increased 15 times. The figure of merit for III was decreased from 0.265 to 0.047×10^{-3}, since its thermoelectric power decreased by about 30%. Cationic substitutional solid solutions of I and II did not increase the figure of merit.

1909
New York University. College of Engineering, New York, N. Y. A STUDY OF A CLASS OF INTERMETALLIC COMPOUNDS, THE CHALCOPYRITES, Summary Report, by S. Zalar and I. Cadoff. 54p., illus., Oct. 1960. (ARL TR 60-316) (Contract AF33(616) 3959) (AD-252 808)

Three compositions of the class of polyatomic semiconductors of the chalcopyrite structure, A (I) B (III) C2 (6+) were investigated by thermal, microscopic, mechanical and electronic methods.

1910
New York University. College of Engineering, New York, N. Y. THERMOELECTRIC PROPERTIES OF INTERMETALLIC COMPOUNDS. 3p., Dec. 1959, Mar., June 1960. (Prog. Repts. 12, 13, 14) (Contract AF33(616)-3883)

Work was concentrated on the series of alloys of composition $Sn_xPb_{1-x}Te$.

1911
New York University. Department of Chemistry, New York, N. Y. THERMOELECTRIC PROPERTIES OF THE SILVER NITRATE/SODIUM NITRATE SYSTEM, by R. Schneebaum and B. R. Sundheim. 8p., June 19, 1961. (Contract Nonr-285-37) (AD 258 756)

The determination of the initial thermal emf at 310° C in the system $Ag(T_1)/AgNO_3$, $NaNO_3/Ag(T_2)$ is described for the complete composition range. The thermoelectric power of pure $AgNO_3$ (319 v/° C) falls off slightly as the mole fraction of $AgNO_3$ decreases and then rises sharply in dilute solutions. Extrapolation towards zero mole fraction of $AgNO_3$ gives a value of 797 v/° C. The phenomenological equations are presented in a form well suited to the study of liquid electrolytes. For systems with the particularly simple transference properties of this system, the initial emf is $-(Q_1^w - Q_3^w/T$ where Q_1^w is the heat of transport for interdiffusion and Q_3^w is the Peltier heat in the Soret steady state ($= S_{Ag} - S_{Ag} - S_{el}$). The final emf in the steady state is $-Q_3^w/T$, so that the present results can be combined with the forthcoming Soret effect data to give the heat of diffusional transport and the "entropy of the moving ion."

1912
Nikitin, E. N. THERMOELECTRIC PROPERTIES OF THE SILICON-CHROMIUM SYSTEM. Fiz. Tverdogo Tela 2:2685-2688, Nov. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2389-2392, figs., May 1961.

The paper describes a detailed study of thermoelectric properties of the silicon-chromium system. The aim was to obtain materials with the optimum parameters and to find phase composition from the "singular" points on the electrical conductivity or thermoelectric power curves.

1913
NOT-SO-RARE EARTHS TAKE AIM ON NEW USES. Chem. Wk. 88:59-61, May 13, 1961.

A brief statement is included to the effect that thermoelectric materials based on rare earths are under close study. Gadolinium selenide and the sulfides of samarium and cerium are mentioned in particular.

1914
Ohio State University Research Foundation, Columbus, Ohio. THERMOELECTRIC MATERIALS. 5p., Sept. 4, 1960. (Rept. 4) (Contract Nobs-78254) (AD 258 340)

Concerns the effect of temperature difference on the emf in μ V/° C in the molten temperature range of $Na_2O \cdot 6V_2O_5$. Studies of NV_6 have shown it to be a promising thermoelectric material with a maximum emf of about 700 μ V/° C in air.

1915
Palme, A. THERMOELECTRIC INVESTIGATIONS. Z. Elektrotech. Wien 23:413-414, Jly. 2, 1905.

In German. The paper contains an account of some thermoelectric investigations, the results of which are embodied in a series of curves. The investigations were undertaken mainly with the object of determining combinations suitable for purposes of pyrometry. Among those giving an approximately straight-line law for the relation connecting emf and temperature were found to be the following: platinum-carbon, silver-copper, German silver-iron, constantan-iron. (Sci. Abs. 8A:1795, 1905)

1916
Pappis, J. and Kingery, W. D. ELECTRICAL PROPERTIES OF SINGLE-CRYSTAL AND POLYCRYSTALLINE ALUMINA AT HIGH TEMPERATURES. Am. Ceram. Soc. J. 44:459-464, figs., Sept. 1961.

Thermoelectric emf measurements, the oxygen-pressure dependence of electrical conductivity, and the temperature dependence of electrical conductivity for aluminum oxide indicate that this material is an amphoteric nonstoichiometric semiconductor.

1917
Plaksin, I. N. and Shafeev, R. Sh. THE EFFECT OF CERTAIN SEMICONDUCTOR SURFACE PROPERTIES ON THE REACTION OF XANTHATE WITH GALENA. Akad. Nauk. SSSR. Dok. 132:399-401, May 11, 1960.

In Russian. A short discussion of the surface electrical properties of an extrinsic semiconductor with which adsorbed oxygen acts as an acceptor. It is suggested that xanthate can bond readily only to a p-type surface. The latter may be formed on n-type material through oxygen adsorption. A thermoelectric probe apparatus is described and measurements of thermo-emf to 400° C are briefly reported for galena, chalcopyrite, molybdenite and pyrites. The first two were n-type, the others p-type. (Sci. Abs. 63A:15953, 1960)

1918
Port, John. RHENIUM: A PROMISING REFRACTORY METAL. Mat. Design Eng. 51:140-142, 1960.

Re is the most refractory metal that can be electro-deposited from an aqueous solution, it is superior to W in resistance to deterioration caused by the "water cycle", it has low contact resistance, does not form stable carbides, has greater ductility at room temperature than W, and has good thermoelectric properties when joined to W or Mo. Mechanical properties and application of Re in welding filler metal (Mo-35% Re alloy to join Mo components), thermocouples, electrical contacts, and heaters and filaments in electron tubes are discussed. (Met. Abs. 28:644, 1961)

1919
Poslawski, R. P. SEMICONDUCTOR MATERIALS PROVIDE KEY TO THERMOELECTRIC DEVELOPMENTS. Can. Electron. Eng. 5:29-31, 39, Feb. 1961.

Research is opening up new market prospects for such devices. Surveys show that supply of raw materials can keep up with demand.

1920
Princeton University. Plastics Laboratory, Princeton, N. J. SEMICONDUCTING POLYMERS, by H. A. Pohl, J. A. Bornmann, and W. Itoh. 9p., Jan. 30, 1961. (Tech. Rept. 60-C) (Contract DA36-039-sc-78105)

High polymers of the condensed phenolphthalein type have been prepared and studied with respect to their electronic properties. Fifty-two such polymers have been prepared by condensation polymerization at 256° and 316° C. Studies of the conductivity-temperature characteristics, and of the thermoelectric powers give data which can be fitted by a two carrier band theoretical model.

1921
PROMISING THERMOELECTRIC MATERIAL. Aviat. Wk. & Space Tech. 75:81, Nov. 6, 1961.

"Bell Telephone Laboratory scientists have developed new thermoelectric material using bismuth-antimony which has figure of merit of 0.005, nearly twice as good as any other known material, at low temperatures of around 80° K. This suggests material will find use for Peltier cooling rather than as a thermoelectric generator." Entire item quoted.

1922
Puotinen, D. and Newnham, R. E. THE CRYSTAL STRUCTURE OF $MoTe_2$. Acta Crystall. 14:691-692, June 10, 1961.

A study of the thermoelectric properties of phases in the Mo-Te system confirms the existence of Mo_2Te_3 and $MoTe_2$. The structure of the latter was determined by x-ray diffraction to be hexagonal with a = 3.519 A and c = 13.964 A. Isomorphism with molybdenite is noted. Random-orientation intensities were compared and structure factors were computed. (Crerar Met. Abs. 9:2553, Jly. 1961)

1923
Purdue Research Foundation, Lafayette, Ind. SEMICONDUCTOR RESEARCH. 6 issues, 1952, 1953, 1954. (Quart. Repts. 6, 7, 8, 9, 10, 11) (Contract DA 36-039-sc-15339) (AD-3377, AD-14 460, AD-25 189, AD-43 314, AD-43 313, AD-50 583)

Research included a study of the thermoelectric power of Ge.

1924
Purdue Research Foundation, Lafayette, Ind. SEMICONDUCTOR RESEARCH. 4 issues, illus., 1954, 1955. (Quart. Repts. 1, 2, 3, 4) (Contract DA 36-039-sc-63222) (AD-54 194, AD-64 264, AD-80 497, AD-80 496)

Work is reported on the calculated behavior of the thermoelectric power of InSb at high temperatures.

1925
Purdue University. Department of Chemistry, Lafayette, Ind. STOICHIOMETRY, RESISTIVITY AND THERMOELECTRIC POWER OF CERIUM DIOXIDE BELOW 500° C, by A. W. Czanderna and J. M. Honig. 27p., Sept. 1957. (AFOSR TN-57-602) (Contract AF18 (603)-45) (AD-136 591) (PB 132 133)

Experimental studies on changes in stoichiometry of ceria at low temperatures are presented, together with attempts to correlate the changes in oxide composition with thermoelectric power and conductivity measurements.

1926
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. THERMOELECTRIC MATERIALS FOR POWER CONVERSION, by B. Abeles, C. D. Cody, et al. 2 issues, Nov. 15, 1960, Feb. 15, 1961. (Quart. Prog. Repts. 7, 8 (Final)) (Contract Nobs-77057) (AD-258 953 (no. 7))

Materials research is reported on bismuth telluride alloys, ternary compounds silicides and sulfides

for use in power generating thermocouples.

1927
RARE EARTH THERMOELECTRICS FUNCTION AT HIGH TEMPERATURES. Chem. & Eng. News 39:48, illus., Mar. 20, 1961.

It is reported that the sulfides are refractory materials with excellent high temperature stability and good thermoelectric efficiencies at temperatures as high as 2000° F.

1928
Redemske, R. F. MATERIALS FOR THERMOELECTRIC CONVERSION. In Power Sources Conference, Proceedings, 14th, p. 4-7, Red Bank, N. J., PSC Publications Committee, 1960.

The influence of materials on the thermoelectric-cell efficiency and ways of improving this influence are discussed. The material should be selected to maximize the figure of merit Z. General rules for the selection of thermoelectric materials are given. The plots of Z vs. absolute temperature T show that the Z maxima of the different materials and doping levels form a curve approximately defined by ZT = 1, which appears to impose an upper limit on the performance of thermoelectric materials. The efficiency was calculated for a constant cold-junction temperature of 300° K with a continuously upgraded material with z at a maximum all along the material length and plotted vs. the hot-junction temperature; it reaches 20% at 1500° K. (Nuclear Sci. Abs. 15: 11862, 1961)

1929
Rheinhold, H. and Schmitt, K. ELEKTRISCHE LEITFAHIGKEIT UND DIFFUSION IN HALMETALLISCHEN LEGIERUNGEN. (ELECTRICAL CONDUCTIVITY AND THERMOELECTRIC POWER OF ALPHA Ag_2S). Z. Physik. Chem. 44:75-108, 1939.

In German. The thermoelectric power of the junction of Pt-alpha Ag_2S was determined for several different S pressures. Data indicate that there is a relationship between conductivity and thermoelectric power and that conductivity is proportional to electron concentration. The electrical conductivity of Ag_2S in S vapor depends on the dimensions of the vessel in which the determination is carried out. This is caused by dissociation and recombination of S molecules of fairly low velocity. A "streaming method of velocity determination" is described.

1930
Rodot, Huguette. STUDY AND PROPERTIES OF THE SYSTEM $AgSbTe_2$-PbTe. Acad. Sci. Paris. Compt. Rend. 249:1872-1874, 1959.

In French. The temperature of fusion, the electric conductivity σ and the thermoelectric power α are determined as a function of the composition.

1931
Rosi, F. D., Hocking, E. F. and Lindenblad, N. E. SEMICONDUCTING MATERIALS FOR THERMOELECTRIC POWER GENERATION. RCA Rev. 22:82-121, figs., Mar. 1961.

A general consideration of the thermoelectric properties of semiconductors suggests that (1) this class of materials can be useful in power-generating thermocouples operating at least up to 700° C, and (2) use of a sandwich-type arrangement or graded alloying in the construction of thermocouple branches will be necessary to achieve high figures of merit over a wide temperature range and, hence, high power-generating efficiencies.

1932
Rudnitskii, A. A. and Tyurin, I. I. ALLOYS FOR THE FABRICATION OF HIGH TEMPERATURE THERMOCOUPLES. Zhurn. Neorg. Khim. 5:401-409, 1960.

In Russian. In a search for thermoelectric materials for high temperature thermocouples, metals and alloys of different compositions were investigated. These included pure iridium and rhodium, binary alloys of platinum with rhodium and iridium with rhodium, and ternary alloys based on platinum with rhodium, ruthenium, iridium, and palladium. (Ceram. Abs. 44:147, June 1961)

1933
Saburi, O. PROPERTIES OF SEMICONDUCTIVE BARIUM TITANATES. Phys. Soc. Japan J. 14:1159-1174, Sept. 1959.

$BaTiO_3$ ceramics were rendered semiconducting by the replacement of a small proportion (0.1 to 0.3%) of Ba or Ti ions by ions of higher valency. Conductivity measurements over a range of temperatures are reported for many specimens, all of which show an anomalous, negative, temperature coefficient of conductivity in the region of the phase transition at 120° C. Other semiconducting properties investigated are thermoelectric power, Hall effect, rectification, and the variation of permittivity and a.c. conductivity with frequency and temperature. The discussion deals with the types of ion found to produce conductivity and with the dielectric measurements. (Sci. Abs. 64A:1070, 1961)

1934
Sakata, K. THERMOELECTRIC BEHAVIORS OF RUTILE. Phys. Soc. Japan. J. 16:1026, May 1961.

The present note describes the results of experiment in which the temperature dependence of conductivity and that of thermo-emf were simultaneously measured for rutile samples sintered in different oxygen atmosphere.

1935
Savornin, F. THERMOELECTRIC POWER AND MEAN FREE PATH IN THIN SLICES OF COBALT. Acad. Sci. Paris. Compt. Rend. 248:3133-3135, June 1, 1959.

In French. The thermoelectric power of cobalt was measured as a function of specimen thickness at 423° K with respect to silver. The results were in agreement with theory, and for the bulk material a value of $\phi Co-\phi Ag = -30.5 \pm 0.5$ μ v/deg K was obtained. Assuming Bloch's relation between mean free path ℓ and energy E, $\ell \propto E^n$, a value of $n = 2.3 \pm 0.5$ is deduced.

1936
SCRATCH ONE BREAKTHROUGH. Aviat. Wk. 75:75, Jly. 10, 1961.

"Unusually high figure of merit for a rare earth thermoelectric material (gadolinium selenide), reported last year by a scientist with Nuclear Corp. of America, has not been verified by independent measurements. It was claimed that gadolinium selenide had a figure of merit of 0.045/deg. at 800° C—50 times better than any previously known material for thermoelectric power generation—a substantial step forward in thermoelectric conversion. Material is still considered promising, as it had been before Nuclear's announcement, but is not appreciably better than any other competitive materials." Entire item quoted.

1937
Shashkov, Yu. M. THE METALLURGY OF SEMICONDUCTORS. Authorized translation from the Russian by J. E. S. Bradley. 183p., figs., New York, Consultants Bureau, 1961.

Only two main semiconductor materials are considered: these two (germanium and silicon) are similar in properties. Topics dealt with are: purification of materials, growth of monocrystals, diffusion of the main doping elements in germanium and silicon, heat treatment, doping and production of heterogeneous electrical structures in monocrystals, preparation of ohmic contacts, and etching.

1938
Sirota, N. N., Samsonov, G. V. and Strel'nikova, N. S. ELECTRICAL PROPERTIES OF SOME METAL-LIKE COMPOUNDS AND THEIR SOLID SOLUTIONS. Symposium, Nauch. Trudy Moscow, Inst. Tsvet. Met. i Zolota, Naucho-Tekhn. o-vo Tsvet. Metallurgii, no. 30:368-374, 1957.

In Russian. Results are given of measurements of specific electrical resistance and thermal-emf in a couple of Cu with several carbides, silicides, borides, nitrides and some of their binary alloys; also a preliminary determination of magnetic susceptibility of several binary alloys of these compounds. Samples for test were prepared by the hot pressing method. On the basis of the electronic structure of the test-pieces some of the results of the work are discussed. (USSR. Abs. Metall. Part B, no. 10;219, 1958)

1939
Smirous, K. PROPERTIES OF SEMICONDUCTING SYSTEMS ON THE BASIS OF COMPOUNDS OF THE TYPE $A^{II}B^{V}$. In International Conference on Solid State Physics, Electronics, and Telecommunications, Brussels, 1958, Proceedings, 2(Pt. 2) p. 779-783, New York Academic Press, 1960.

The specific conductivity, thermoelectric power, and thermal conductivity were determined for solid solutions of ZnSb and CdSb in the complete range of concentrations.

1940
Smith, G. E. and Wolfe, R. THERMOELECTRIC POWER OF BISMUTH-ANTIMONY ALLOYS AT LOW TEMPERATURES. Am. Phys. Soc. Bull. 6:137, Mar. 20, 1961.

Abstract only of paper given at the 1961 March meeting of the American Physical Society, Monterey, Calif.

"The thermoelectric power, resistivity, and thermoelectric figure of merit have been measured in the temperature range between 300° K and 20° K for alloys in the range of 5% to 40% antimony in bismuth. Galvanomagnetic measurements by Jain have shown that these alloys exhibit semiconducting characteristics which have a maximum effective gap of 0.014 ev for concentrations of about 12% antimony in bismuth. For the 12% alloy, the thermoelectric power is n-type and shows a gradual rise from 125 μv/° K at 300° K to 150 μv/° K at 80° K and then falls off rapidly. The figure of merit Z shows the same behavior and has a maximum of $Z = 5 \times 10^{-3}$ at 80° K. In a 12% alloy doped with 0.01% lead, the thermoelectric power changes from n-type at high temperatures to p-type at temperatures below 40° K. The use of this material in a low-temperature thermoelectric refrigeration seems feasible." Entire item quoted.

1941
Snyder, P. E. CHEMISTRY OF THERMOELECTRIC MATERIALS. Chem. & Eng. News 39:102-108, 111-112, Mar. 13, 1961.

Both in this country and abroad, research workers are intensifying their quest for new materials to produce more efficient thermoelectric devices--now being used on a limited scale for cooling and power generation.

1942
South Dakota School of Mines and Technology, Rapid City, S. D. HIGH-TEMPERATURE THERMAL CONDUCTIVITY IN BISMUTH TELLURIDE (Bi_2Te_3) AND SILICON (Si)., by J. G. Hust. 87p., illus., 1960. (Tech. Rept. 2) (Contract Nonr-2964(01)) (AD-251 689)

Master's Thesis.

The thermal conductivity of two samples of p-type polycrystalline bismuth telluride and two samples of p-type single-crystal silicon was measured by a series comparative method from 30 to 330° C for bismuth telluride and 30 to 425° C for

silicon. Armco iron was used as the standard material. Lowest-resistance thermal contacts between the standards and the sample were obtained with powdered graphite in sodium silicate solution. These good contacts greatly reduce radiation loss between the samples and the surroundings. Radial heat flow was further reduced by placing the sample holder in a vacuum of about 1/100,000 mm of Hg, by surrounding the standard-sample-standard sandwich with a three-piece Lava radiation shield, and by clamping the thermocouple wires in a Lava heat sink. The average room temperature thermal conductivity of Bi_2Te_3 is 0.005 cal/cm sec degree C. The thermal conductivity of silicon is found to vary linearly with the reciprocal of the absolute temperature, having a value of 0.30 cal/cm sec degree C at 30° C and a value of 0.11 cal/cm sec degree C at 425° C. These results indicate that the lattice conductivity is predomirrant in this temperature range.

1943
Spadavecchia, G. MAGNETISM AND THE THERMOELECTRIC PROPERTIES OF BISMUTH AND ITS ALLOYS. Nuovo Cimento 9:432-446, June 1899.

Variations in the thermoelectric emf of the alloys of bismuth and tin under the influence of a magnetic field increase with increase of the variations in that field, and have different values according to the direction of the magnetization. Under the influence of a given magnetic field the variations of the thermoelectric emf diminish from pure bismuth to an alloy containing 0.113% of tin, changing sign between 0.056% and 0.113%; then the variations increase up to 0.237%, changing sign between this and 2%. The sign changes again for an alloy between 80 and 83% of tin. (Sci. Abs. 2:1931, 1899)

1944
Spitzer, W. G., Wernick, J. H., and Wolfe, R. ELECTRICAL AND OPTICAL PROPERTIES OF $CdSnAs_2$. Solid-State Electron. 2:96-99, figs., Mar. 1961.

The electrical and optical properties of n-type $CdSnAs_2$ have been investigated for samples having carrier concentrations between 1 and 3×10^{18} cm^{-3}. Resistivity and Hall coefficient measurements yield room-temperature electron Hall mobilities between 6200 and 5500 cm^2/V-sec in this carrier concentration range. Measurements between room temperature and liquid-helium was observed with an approximate energy gap of 0.3 e.v. A thermal-conductivity measurement yielded a phonon thermal conductivity of 0.071 W/cm° C. For the same carrier concentrations, the thermoelectric power ranged from -100 to -70 μV/° C, indicating a thermoelectric figure of merit on the same samples used to obtain the electrical data. An electron effective mass between 0.04 m_o and 0.06 m_o and a lattice dielectric constant of 12.1 ± 0.4 were deduced from the reflectivity data. The shift in the absorption edge with increasing carrier concentration and the free-carrier absorption yielded electron effective masses in qualitative agreement with the values obtained from the reflectivity data.

1945
STILL IN THE EARLY STAGES: NEW THERMOELECTRIC MATERIALS THAT MAKE ELECTRICITY DIRECTLY FROM HEAT. Mill & Factory 63:118-119, Dec. 1958.

A news item states that ceramics developed by Westinghouse are believed to be the first solid state thermoelectric substance to operate in the temperature range from 200° to 3000° F.

1946
STUDIES OF SHOCK PROPAGATION, VIBRATION AND THEIR INSTRUMENTATION. Rept. NRL Prog. p. 21-22, Sept. 1960.

This progress report summarizes the results of thermoelectric power measurements on the dehydrogenated palladium.

1947
Susuki, M. and Mizuguchi, K. THE THERMOELECTRIC FORCE OF COPPER-CONSTANTAN THERMOCOUPLES IN THE TEMPERATURE REGION OF LIQUID OXYGEN. Electrotech. Lab. Bull. (Japan) 23:35-39, Jan. 1959.

In Japanese. The thermo-emf was measured in the temperature range of 60-90° K. The measuring apparatus used is described and an equation for the thermo-emf over this range is given.

1948
Sutter, P. H. DIFFUSION. In Heikes, R. R. and Ure, R. W., Jr. eds. Thermoelectricity; Science and Engineering, p. 154-180, New York, Interscience Publishers, 1961.

Various aspects of diffusion are discussed and important considerations with respect to uses of materials in thermoelectric devices are pointed out.

1949
Systems Research Laboratories, Dayton, Ohio. THE ELECTRICAL BEHAVIOR OF REFRACTORY OXIDES, by R. W. Vest. 8p., illus., Mar. 21, 1961. (Rept. 203) (Contract AF33(616)7748) (AD-255 079)

A study was begun on the electrical properties of refractory oxides. Initial measurements to be made on single crystals and polycrystalline ZrO_2 will include electrical conductivity, thermoelectric power, dielectric constant, and polarization voltages. A hot press is being designed for operation in vacuum or an inert atmosphere at 2000° C and 4000 psi. By replacing the die with a W susceptor, the unit can be converted to a high-temperature vacuum furnace. Preliminary studies were made of the preparation of dense ZrO_2 by hydrostatic pressing (4000 to 17,000 psi) and sintering in vacuum at 1800 to 1950° C. An attempt will be made to grow single crystals from the vapor phase of the reaction between $ZrCl_4$ and oxygen near 1000° C.

Details are presented of an experimental apparatus for the measurement of electrical conductivity, dielectric constant, and thermoelectric power. Fast and slow polarization voltage measurements will be made initially on single crystal sapphire with the apparatus for conductivity measurements.

1950
Telkes, Maria. MATERIALS FOR SOLAR THERMOELECTRIC GENERATORS. In Conference on the Use of Solar Energy--the Scientific Basis, Tucson, 1955. Transactions vl. 5:1-7, Tucson, University of Arizona, 1958.

Theoretical calculations and results of experiments with various thermoelectric materials; experimental results on efficiency of solar thermoelectric generators.

1951
Tennery, V. J. and Cook, R. L. INVESTIGATION OF RARE-EARTH DOPED BARIUM TITANATE. Am. Ceram. Soc. J. 44:187-193, Apr. 1, 1961.

In this study the effect of additions of 0.0015 to 0.0030 mole fraction of rare-earth oxides on the d-c resistivity of sintered barium titanate was investigated. The substitution may be represented by $(X_2O_3)_M (BaTiO_3)_{1-M}$, where X is the rare earth. The rare earths samarium, gadolinium, and holmium were introduced singly into the titanate, and the resistivity was measured as a function of temperature from -170° to +330° C. An anomalous increase near the tetragonal > cubic transition temperature at 120° C occurred which in some cases amounted to an increase in the resistivity of 4000 times the value in the tetragonal phase. The thermoelectric power of the material changed sign at the Curie temperature. The tetragonal phase exhibited n-type behavior whereas the cubic phase was p-type. The rhombohedral and orthorhombic phases exhibited conduction activation energies of the order of 0.2 ev whereas that in the

tetragonal phase was approximately 0.1 ev.

1952
Teranishi, S. and Tarama, K. MAGNETIC AND ELECTRIC PROPERTIES OF VANADIUM TRIOXIDE. J. Chem. Phys. 27:1217-1218, Nov. 1957.

Thermoelectric power measurements indicate that the vanadium trioxide samples are all n-type at 1×10^{-3} mm of Hg. However, these n-type specimens change to p-type when oxygen is admitted at high temperatures. It appears that V + 2 ions exist in vanadium trioxide, but that V + 4 ions are created when oxygen is admitted.

1953
THERMOELECTRIC COOLER: NEELIUM S. Elec. Mfg. 66:142, illus., Aug. 1960.

Neelium S is a semiconductor alloy consisting of bismuth, tellurium, selenium, and antimony. Neelium semiconductor, used in a thermoelectric cooler withstands ambients 160° C, with special types capable of 300° C operation.

1954
Tiller, W. A. CRYSTAL GROWTH. In Heikes, R. R. and Ure, R. W., Jr., eds. Thermoelectricity; Science and Engineering, p. 181-231, New York, Interscience Publishers, 1961.

The two primary methods of thermoelectric materials preparation, (1) pressing and sintering, and (2) crystal growth from the melt, are mentioned. In the second method, the material is melted to produce bonding and homogenization and is then frozen. Details of the freezing problems are discussed.

1955
Transitron Electronic Corp., Wakefield, Mass. THERMOELECTRIC MATERIALS. 18p., figs., Mar. 3, 1961. (Quart. Prog. Rept. 6) (Contract Nobs-7845) (PB 155 597)

Experimental results are reported on the investigation of the $Cr_{1-x}M_xSi_{2.00}$ and $Mn_{1-x}M_xSi_{2.00}$ series of compounds prepared by the argon arc technique. The trends in the thermoelectric power parameters are found to deviate from those predicted on the hypothesis developed in Report 5. In order to realistically evaluate the materials of interest, alloys are being prepared by induction heating followed by a carefully controlled slow cool. Materials prepared in this way show improved properties. The optimization of the thermoelectric properties of the compounds $MnSi_2$ and $Mn_{1-x}M_xSi_{2.00}$ has been attempted by making Ag, Au and Sn additions. The properties are improved.

1956
Transitron Electronic Corp., Wakefield, Mass. THERMOELECTRIC MATERIALS. Final Report, January 4, 1960 - July 3, 1961. 35p., Jly. 1961. (Contract Nobs-78345)

As a practical result of work on n-type thermoelement CoSi + 1% FeSi and a p-type thermoelement $Cr_{0.25}Mn_{0.95}Si_2$-2% Ag have been developed. These materials, like most of the transition metal silicides, are stable thermally and with Z values of the order of 0.5×10^{-3} °K they offer much as practical thermoelectric materials.

1957
Ure, R. W., Jr. and Heikes, R. R. THEORY OF THERMOELECTRIC MATERIALS. In Heikes, R. R. and Ure, R. W., Jr., eds. Thermoelectricity; Science and Engineering, p. 339-388, New York, Interscience Publishers, 1961.

The figure of merit of broadband and narrow-band semiconductors is treated, also mixed valence semiconductors, ionic crystals, and liquids. The chapter concludes with a treatment of the problems of materials selection and improvement of known materials.

1958

U.S. Army Signal Research and Development Laboratory. Ft. Monmouth, N. J. PREPARATION AND PROPERTIES OF THERMOELECTRIC MATERIALS. 8p., Apr. 30, 1961. (Quart. Prog. Rept. 3) (Contract DA91-591-EUC-1505)

An investigation is reported on the preparation of the compounds of the (Mo, W) (Se, Te)$_2$ type.

1959

U.S. Atomic Energy Commission. Oak Ridge National Laboratory, Oak Ridge, Tenn. IN-PILE MEASUREMENT OF THE ELECTRICAL RESISTIVITY AND THERMOELECTRIC POWER OF SINTERED UO_2. 12p., May 2, 1961. (Rept. 3093) (Contract W7405-eng-26)

The thermoelectric emf for the Pt-UO_2-Pt system ranged from 130 μv/° C at 162° C to 29 μv/° at 900° C.

1960

Vedernikov, M. V. and Kolomoets, N. V. THERMOELECTRIC PROPERTIES OF SOLID SOLUTIONS OF CHROMIUM, VANADIUM AND TITANIUM IN NICKEL. Fiz. Tverdogo Tela 2:2718-2727, Nov. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2420-2427, figs., May 1961.

The paper deals with thermoelectric properties of binary alloys of nickel with chromium, vanadium, and titanium. These alloys were single-phase solid solutions at all test temperatures.

1961

Verstrepen, J. W. A STUDY OF THE SEMICONDUCTING PROPERTIES OF SELENIDES AND TELLURIDES OF GERMANIUM AND TIN. Acad. Sci. Paris. Compt. Rend. 251:1273-1274, Sept. 26, 1960.

In French. Compounds were prepared from spectroscopically pure components. The tellurides were highly degenerate with $p \sim 10^{-4}$ ohm cm and a thermoelectric power of $\sim 50\ \mu V$/deg C for temperatures between 140 and 800° K. The selenides show typical semiconducting properties. The resistivity varies from 10^3 ohm cm at low temperatures to 10^{-4} ohm cm at high temperatures. The thermoelectric power is $\sim 600\ \mu V$/deg C at room temperature but decreases rapidly with increase in temperature. The properties of mixtures of selenides and tellurides were examined. (Sci. Abs. 64A:1043, 1961)

1962

Vickery, R. C. and Muir, H. M. ANOMALOUS THERMOELECTRIC PROPERTIES OF GADOLINIUM SELENIDE. Nature 190:336-337, Apr. 22, 1961.

A preliminary attempt is made to correlate and explain anomalies which are pointed out.

1963

Vidusova, T. A. INVESTIGATION OF ALLOYS OF PALLADIUM WITH RHENIUM. Izvest. Sektora Platiny i Drug. Blagorod. Metall. Inst. Obshchei i Neorg. Khim. Akad. Nauk. SSSR. no. 28:251-255, 1954.

In Russian. The thermoelectric powers of these two alloys against Pt were: 28°, -0.114, +0.130 mv.; 61°, -0.238, 0.079; 89°, -0.356, 0.134; 100°, -0.395, 0.154; 529°, -3.165, 1.483; 645°, -4.410, 1.827; 711°, -4.950, 1.979; 750°, -5.831, 2.004; 771°, -6.000, 2.164; 813°, -6.651, 2.227. The absolute thermoelectric power in microvolts per degree was found to be: 0% Re, -11.02; 4.06, +2.28; 7.39, 4.49; 20.37, 6.21; 28.65, 9.85; 40.02, 8.12; 45.63, 5.89.

1964

Voitenko, R. M. and Raskina, E. M. ON SOME PROPERTIES OF SEMICONDUCTING POLYMER MATERIALS. Akad. Nauk. SSSR. Dok. 136:1137-1138, Feb. 11, 1961.

In Russian. The variation of electrical conductivity and thermoelectric power with temperature was examined for several specimens of polyacrylonitrile. The conductivity varies exponentially with temperature in the usual way while the thermoelectric power remains almost independent of temperature over the same range. This evidence is used to show that the conductivity variation temperature is due to an exponential variation of carrier mobility.

1965
WESTINGHOUSE DISCOVERS PROMISING THERMIONIC MATERIALS. Nucleonics p. 31, Oct. 1958.

A series of mixed-valence ceramics promising heat to electricity conversion efficiencies of 20% has been discovered by Westinhouse. The materials have achieved efficiencies of 7% and offer the prospect of 20% within 2-3 years.

1966
Westinghouse Electric Corp. Research Laboratories, Pittsburgh, Pa. THERMOELECTRICITY. 117p., illus., 1960. (Quart. Prog. Rept. 4) (Contract Nobs-78365) (AD-259 564)

This report includes: THE ELECTRICAL PROPERTIES OF PURE AND DOPED $AuTe_2$, by C. Zener. 18 Oct 60

THE FIGURE OF MERIT OF N-TYPE PbTe, by M. S. Lubell, P. E. Snyder and others. 8 Nov 60

ANALYSIS OF INSULATION ERROR IN THERMAL CONDUCTIVITY COMPARISON MEASUREMENTS, by J. E. Bauerle. 23 Sep 60

There were small improvements in efficiencies of ZnSb and the quaternary Bi, Sb, Se, Te alloys. Preliminary results on alloys of the form (Ag2Te2) (Sb2Te3) indicate these materials will be considerably better than ZnSb over its whole temperature range. However, because of the difficulties of measuring such low thermal conductivities by relative methods, these data will not be included until absolute measurements have been completed over most of the temperature range. Another useful thermoelectric material, Te doped CoSb3 was developed. This material has nearly as high a differential efficiency as PbTe (epsilon = 12.7% at 800 K as compared to 15% for PbTe + .10% Bi at the same temperature) and appears to have considerably better mechanical properties than PbTe. The survey of compounds having cubic or near cubic structures was continued. The results indicate that materials with a differential efficiency in excess of 15% will be obtained.

1967
Wyrick, R. and Levinstein, H. THERMOELECTRIC VOLTAGE IN LEAD TELLURIDE. Phys. Rev. 78:304-305, May 1, 1950.

The thermoelectric power of an evaporated lead telluride film containing an excess of Te rises and then drops to zero at the resistance maximum, and then reverses, when baked in vacuum. If PbTe contains an excess of Te conduction is by positive holes as is indicated by the positive thermoelectric voltage. Baking removes Te and results in an excess of Pb. Diffusion of oxygen into the lattice changes the film from an electronic to a hole conductor.

1968
Yamashita, Tadayoshi and Ohta, Tokio. MEASUREMENT OF SEEBECK EFFECT IN PLASTICALLY BENT GERMANIUM. Phys. Soc. Japan. J. 16:1565-1569, figs., Aug. 1961.

The changes of the thermoelectric powers and the electrical resistivities of several kinds of n-Ge and p-Ge due to plastic bending are measured in the temperature covering the transition- and intrinsic-ranges and analyzed by the theory. The value of the dislocation-acceptor level is estimated to be about 0.2 ev. The n-Ge sample near intrinsic is converted to p-type by the bending, while n-Ge with low resistivity and p-type samples show the slight

effect. The difference of n-p conversion due to the deformation from the thermal conversion is discussed.

1969
Yur'ev, V. G. THERMOELECTRIC PROPERTIES OF A GASEOUS SEMICONDUCTOR. Fiz. Tverdogo Tela 2:2929-2931, Nov. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2602-2604, figs., May 1961.

The paper gives the preliminary results of an investigation into the physical properties of a weakly ionized gas. During this investigation, opportunity was taken to test the theory of Moizhes and Pikus.

1970
Zener, Clarence. TRANSFER OF HEAT TO ELECTRICITY. Power p. 176, Feb. 1959.

Dr. Zener, director of research for Westinghouse Electric Corp., reports that in his work with nonconductors in thermoelectricity, he has found certain ceramics that at 2000-3000° F change heat to electricity.

1971
Zhuze, V. P., Sergeeva, V. M., and Shelykh, A. I. ELECTRICAL PROPERTIES OF SEMICONDUCTING In_2Te_3 WITH DEFECTIVE STRUCTURE. Fiz. Tverdogo Tela:2:2858-2871, figs., Nov. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2545-2555, figs., May, 1961.

The authors report a study of electrical properties (the electrical conductivity, the thermoelectric power, the Hall effect) of semiconducting In_2Te_3 with a large number of cation vacancies which disturb the lattice periodicity and distort the crystal field. Scattering of carriers on cation vacancies reduced the carrier mobility in In_2Te_3 (and other semiconductors of $A_2^{III}B_3^{IV}$ type); the mobility in In_2Te_3 was much smaller than in similar isoelectronic binary compounds with fewer imperfections. The mobility was independent of temperature in a wide range of temperatures, due to the predominant role of scattering on neutral cation vacancies. Some important properties of In_2Te_3 were determined and the type of its chemical bonding was deduced.

E. Design, Principles of

1972
Angello, S. J. NEW METHODS OF GENERATING ELECTRIC POWER — THERMOELECTRICITY. Mech. World & Eng. Record 140:369-371, Sept. 1960.

Applying the Seebeck effect to power generation.

1973
Angello, S. J., Frank, C. J., Meess, J. D. and others. TECHNOLOGY OF THERMOELECTRIC DEVICES. In Heikes, R. R. and Ure, R. W., Jr., eds. Thermoelectricity: Science and Engineering, p. 536-569, New York, Interscience Publishers, 1961.

Various practical aspects of device design are considered. Examples of actual device calculation are given for several types of generators and refrigerators and construction is shown. The problem of making low-resistance contacts to thermoelectric materials is considered.

1974
Clingman, W. H. NEW CONCEPTS IN THERMOELECTRIC DEVICE DESIGN. Inst. Radio Engrs. Proc. 49:1155-1160, figs., Jly. 1961.

Also in IRE Intern. Conv. Record, 1961, Pt. 6. p174-182.

When optimizing thermoelectric device design for a given set of materials and technology, the system of equations used will be different for various device applications. Whenever efficiency or coefficient

of performance is important in the application, an irreversible thermodynamic analysis of the design problem is useful. In this analysis, the effects of the thermal and electrical circuit on entropy production within the device are considered. The design problem is analyzed by comparing the relative contribution of various parts of the system to the total entropy production. This irreversible thermodynamic approach is illustrated with examples concerning several different design questions. Often qualitative conclusions can be drawn more readily than with other methods.

1975
Ioffe, A. F., Moizhes, B. Ia., Stil'bans, L. S. ON THE POWER APPLICATIONS OF THERMOELECTRIC ELEMENTS (THERMOCOUPLES). Fiz. Tverdogo Tela 2:2834-2857, Nov. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2524-2544, figs., May 1961.

This paper analyzes the modern state of the theory of thermoelements from the point of view of the further improvement of thermoelectric devices.

Translated excerpts appear in Electron. Express 3:22-27, Mar. 1961.

1976
Kaech, A. ON THE EFFICIENCY OF THERMOELECTRIC GENERATORS. ETZ. 78A:182-187, Mar. 1, 1957.

In German. Discusses efficiency of thermoelectric generators and equations for calculation of efficiency of generation of electricity from heat through thermocouples. To get load balancing from high output generators, external resistance must be made very much larger than internal resistances; thermocouples of low thermoelectric effect.

1977
Kerr, D. L. and Gessner, R. L. THEORETICAL EFFICIENCY OF THERMOELECTRIC GENERATORS WITH CONSTANT THOMSON COEFFICIENTS. Paper CP-59-986, presented June 21-26, 1959. New York, American Institute of Electric Engineers.

Consideration is given to determination of the theoretical efficiency of a thermopile generator when the thermoelectric powers of the materials vary in such a manner that the Thomson coefficients are constant. It is concluded that use of the more exact and more complicated expression for efficiency is not necessary for present day thermoelectric materials. (Astron. Info. Lit. Search. 297:177, Dec. 1960)

1978
Kerr, D. L. THERMOELECTRIC ELEMENTS IN SPACE POWER SYSTEMS. In Snyder, N. W., ed. Energy Conversion for Space Power, p. 85-109, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3)

A discussion is presented of some of the characteristics, potentialities, and problems encountered in the design of thermoelectric generators for space applications. One means of classifying the basic configurations possible is according to the means of rejecting heat from the cold junction, i.e., whether it be to a secondary heat transfer fluid which in turn passes through the radiator or whether the generator waste heat is carried directly to the radiating surfaces by thermal conduction from the cold junctions. Presented are results of some studies which have been made of the latter case where the generator is integral with the radiator. Two types of construction have been investigated which can be termed the "sandwich" type and the "side fin" type. Estimates of the minimum weight obtainable from each are presented for particular materials properties. Comparison of these indicates that a combination of the two types of construction will result in the least weight.

Also issued as ARS Tech. Paper 1277-60. 30 yr., New York, American Rocket Society, 1960.

1979
Mette, Herbert. POWER GENERATION AND HEAT PUMPING BY THERMOELECTRIC PHENOMENA. Solid State J. 2:23-30, illus., May 1961.

The use of thermoelectric effects for electrical power generation and Peltier heat pumping is traced from its early beginnings to modern applications. From an understanding of the basic physical principles involved, design criteria for these devices are derived by a simplified treatment. The outlook for future uses of these devices is given.

1980
Miller, Barry. AIRBORNE THERMOELECTRIC SYSTEMS STUDIED. Aviat. Wk. & Space Tech. 75:71-72, Sept. 4, 1961.

Concerns a new Navy contract assigned to the Douglas Aircraft Company involving study of the application of the Seebeck effect and Peltier effect in separate systems and a single combined power generation and cooling system. Such sources of heat as the waste heat from jet and rocket engines will be among the promising energy sources that will get careful attention.

1981
Naer, V. A. and Rozhentseva, S. A. DESIGNING SEMICONDUCTOR THERMOPILES FOR REFRIGERATORS. Fiz. Tverdogo Tela 3:1125-1131, Apr. 1961.

In Russian. Trans. in Soviet Phys. Solid State 3:818-821, Oct. 1961.

A new method is presented for the calculation of the thermal, energetic, and temperature characteristics of semiconducting refrigerating units.

1982
Naval Civil Engineering Laboratory, Port Hueneme, Calif. POTENTIAL OF THERMOELECTRIC DEVICES OF BUDOCKS APPLICATIONS, by D. Taylor and J. J. Doman. 12p., Apr. 13, 1961. (Tech. Rept. 142) (AD 254 896 L)

An investigation was made to determine whether any thermoelectric devices or techniques can fit any of the requirements of the Bureau of Yards and Docks. None were found which merit recommendation for replacement of existing BuDocks catalog items.

Note: No automatic release to Foreign Nationals.

1983
Somers, E. V. and Swanson, B. W. SOME HEAT TRANSFER PROBLEMS IN THERMOELECTRIC DEVICES. In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity: Science and Engineering, p. 518-535, New York, Interscience Publishers, 1961.

Refrigeration is discussed in the first section, topics considered being back heat leak through thermal insulation and some cost considerations associated with transferring heat from the hot junctions to the ambient surroundings.

In the second section, the thermal efficiency of a specific type of generator is optimized. The last section deals with some weight and volume considerations in the design of a satellite generator.

1984
Swanson, B. W. DESIGNING A THERMOELECTRIC GENERATOR. Power 105:85-87, diags., Feb. 1961.

Development of efficient thermoelectric materials leads to their experimental use for electric generation. Discusses the factors that must be considered in laying out and designing a thermoelectric generator.

1985
Swanson, B. W., Somers, E. V., and Heikes, R. R. OPTIMIZATION OF

A SANDWICHED THERMOELECTRIC DEVICE. J. Heat Transfer (ASME Trans. Series C) 83:77-82, figs., Feb. 1961)

An analysis is made for optimizing the thermal efficiency of a sandwiched thermoelectric device. Design equations were coded for a digital computer. For suitable input data, the computer determines the thermocouple design that approximately maximizes thermal efficiency of the device. A verification of the analysis indicates that the difference between the approximately optimum efficiency and the optimum efficiency is negligible.

1986
Ure, R. W., Jr. and Heikes, R. R. THEORETICAL CALCULATION OF DEVICE PERFORMANCE. In Heikes, R. R. and Ure, R. W., Jr., eds. Thermoelectricity: Science and Engineering, p. 458-517, New York, Interscience Publishers, 1961.

The performance of thermoelectric devices is considered, principally the Seebeck-effect power generator and the Peltier-effect heat pump.

F. Applications

1. Power Generation

1987
Bateman, P. J. THERMOELECTRIC POWER GENERATION. Contemp. Phys. 2:302-311, figs., Apr. 1961.

Using existing semiconductor materials, it should be possible to produce thermoelectric generators with efficiencies of about 14%. Despite future improvement in material properties it appears unlikely that an efficiency greater than 40% of that of the Carnot cycle can be obtained. This renders thermoelectric devices unsuitable for the large scale production of electric power, and limits their usefulness to certain specialized applications where a suitable heat source and sink are available. When this is the case a generator which would have a power-to-weight ratio comparable with that of conventional small d.c. power sources seems feasible.

1988
Baxter, A. D. NUCLEAR POWER IN FLIGHT. Roy. Aero. Soc. J. 65:565-598, diags., Sept. 1961.

The article is concerned mostly with propulsive power but a paragraph is devoted to modest amounts of auxiliary power provided by thermoelectric conversion.

1989
Bean, B. H. THERMOELECTROSTATIC GENERATOR PROMISES HIGH SPECIFIC POWER. Space/Aero. 35:79-80, 82, 85-86, 88, 90, figs., June 1961.

NASA researchers have found that thermoelectrostatic generators show exceptional promise as power sources for spacecraft propulsion and accessory systems. Such generators, they discovered, could be designed to high specific powers (equivalent to low weight).

A thermoelectrostatic generator essentially is a thin-film capacitor alternately heated by solar radiation and cooled by radiant emission. In this article, the electrostatic and thermodynamic cycles of such a generator are analyzed to show the interaction of the parameters that determine the unit's efficiency. The performance of a hypothetical generator is then summarized on the basis of computer calculations for a system that can realistically be considered feasible. The results prove the thermoelectrostatic generator to be clearly competitive with other forms of chemical and other forms of electric power generation.

In addition, the problems of dielectrics for a thermostatic generator are discussed, and a relationship is outlined for meaningful comparison of chemical and electric propulsion systems.

1990
Campana, R. J. and Roes, J. B. PRELIMINARY DESIGN AND PERFORMANCE EVALUATION STUDY OF A SOLAR THERMOELECTRIC FLAT PLATE GENERATOR. In Snyder, N. W. ed. Space Power Systems, p. 187-217, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

The object of the work reported was to study the design and performance of solar power generators to operate in the Venus-to-Mars radial range from the Sun. The design and performance evaluations are based on experimental performance of the thermoelectric elements and their junctions to metallic sheets.

Results indicate that thermoelectric conversion of solar energy may be accomplished for 70 lb/ekw by a single generator operating in the Sun-centered radial range from Mars to Venus, 30 lb/ekw in the Earth-to-Venus range and 20 lb/ekw in the Venus region. Means of obtaining electrical power for space vehicle needs are discussed. Advantages over other means of obtaining electrical power for space vehicle needs are described.

1991
Carrier Research and Development Co., Syracuse, N. Y. A THERMOELECTRIC GENERATOR. Final Report, by M. G. Ryan, W. E. Sonntag, and N. J. Stevens. 1 in. thick, n.d. (Rept. 12) (Contract Nobs-77092)

This final report describes work done under the subject contract, with emphasis on the major guideposts. Detailed results are included for the performance of the alternate panel design and for the discussion of the earlier design when they add to the understanding of the point being discussed.

Significant sections of the preceding eleven Bimonthly Progress Reports are summarized in Appendix IV.

1992
Curtiss-Wright Corp. Princeton Division, Solar Laboratory, Princeton, N. J. SOLAR THERMOELECTRIC GENERATORS FOR APPLICATION OUTSIDE THE EARTH'S ATMOSPHERE. November 1959-February 1960. 81p., Feb. 1960. (Contract DA44-177-TC-622) (AD 255 310)

The following topics are discussed: collection of solar energy, flat-plate collectors, collectors covered with transparent panes, concentrating collectors, thermoelectric generator efficiency, and thermoelectric materials.

Also included is a literature survey. A bibliography appears on p. 62-68.

1993
Daniel'Bek, V., Kurfirst, S., and Roginskaya, N. THERMOELECTROGENERATOR, TYPE TGK-10. 8p Radio (USSR) no. 9:13-14, 1956.

In Russian. Trans. no. 61-19783, MCL-144/III available from OTS or SLA, $1.10. (AD 255 364)

A device is described that converts the heat of burning "kerogas" into 10 to 12 watts of electrical power with an efficiency of 1 to 3.5%. The device is produced in the USSR for use as a power source for radios in rural areas. (Tech. Trans. 6:175, Aug. 15, 1961)

1994
FUEL CELL USED ON PIPELINE GIVES CATHODIC PROTECTION. Oil & Gas J. 59:96, illus., Mar. 13, 1961.

A brief description is given of a ten watt unit thermoelectric generator powered by natural gas, which gives cathodic protection to 16-in. gas lines of Northern Illinois.

1995
Gardner, J. W. THERMOELECTRIC GENERATION. Elec. Times 139:163-165, Feb. 2, 1961.

The fundamentals and basic physical facts of thermoelectric phenomena are outlined. Some of the newer higher-temperature operating materials which have made possible working generators on a laboratory scale are mentioned briefly. Nuclear applications and the major technological difficulties besetting the exploitation of thermoelectric generation on an industrial scale are discussed. (Fuel Abs. & Current Titles 2:2944, 1961)

1996
General Atomic. John Jay Hopkins Laboratory for Pure and Applied Science, San Diego, Calif. SOLAR THERMOELECTRIC PANELS. 3 issues, Feb. 2, May 8, Aug. 10, 1961. (Repts. 1999, 2259, 2478) (Quart. Repts. 1, 2, 3) (Contract AF33(616)-7676)

This contract involves investigation of flat plate solar thermoelectric conversion panels.

1997
General Electric Co., Lynchburg, Va. THERMOPILE GENERATOR FEASIBILITY STUDY. 29p., Oct. 7, 1958. (Tech. Prog. Rept. 9) (Contract AF33(616)-5291)

Exhibit C of the report is "The Application of Nuclear Reactor Heating to Thermoelectric Generators," by B. Wolfe.

1998
General Electric Co. Aircraft Accessory Turbine Dept. West Lynn, Mass. OPTIMIZATION OF THERMOELECTRIC ENERGY CONVERTERS. 4 issues, Aug. Oct. Dec. 1960, Jly. 31, 1961. (Bimon. Prog. Repts. 2, 3, 4, Final) (Contract Nobs-78403)

Three related areas were investigated in this study with the objective of broadening the ground-work need for improving performance and utilization of thermoelectric energy converters. The study of thermal systems contributed to the extension of knowledge relating the effect of design parameters such as weight, volume, geometric configuration, heat source, and sink, to the efficiency of thermoelectric generators. Encapsulation studies were directed toward increasing the useful temperature range of thermoelectric materials, and toward permitting the use of promising materials which require protective envelopes. Synthesis of new substances was aimed at providing materials capable of increasing the ultimate efficiency of thermoelectric generators, while providing increased understanding of the nature of effective thermoelectric materials, to be used as guidelines to further research.

1999
Hall, R. N. AN ANALYSIS OF THE PERFORMANCE OF THERMOELECTRIC DEVICES MADE FROM LONG LIFETIME SEMICONDUCTORS. Solid-State Electron. 2:115-122, fig., Mar. 1961.

The performance of an ohmic-n-p-ohmic junction rectifier made from a long-lifetime semiconductor is analyzed as a thermoelectric generator and as a refrigerator. An upper limit to the efficiency of this device is shown to be inferior to that of a conventional (zero-lifetime) thermoelement.

Arguments are presented to show that any semiconductor device, in which non-equilibrium concentrations of minority carriers play a part in determining the electrical characteristics, will have a poor thermoelectric efficiency. It seems safe to make the generalization that lifetime is not an important material property for semiconductor thermoelements.

2000
Honeywell Research Center, Hopkins, Minn. DEVELOPMENT OF A SEMICONDUCTOR FILM-TYPE THERMOCOUPLE ENERGY CONVERTER. 17p., illus., Apr. 1, 1961. (Quart. Tech. Rept. 6) (Contract DA11-022-501-ORD-3230) (AD-258 075)

An oxide thermoelectric generator was constructed. The properties of this generator are described. The unit establishes the usefulness of oxide thermoelectrics in applications where voltage at low current levels is required.

2001
Huffman, F. N. and Gross, L. W. PERFORMANCE DATA AND ENVIRONMENTAL TEST RESULTS OF SNAP III. In Planetary and Space Science, vl. 4, Proceedings of the Fourth AFBMD/SRL Symposium. Advances in Ballistic Missile and Space Technology, p. 226-241, New York, Pergamon Press, Jan. 1961.

Although SNAP III was designed primarily as a proof-of-principle device, the electrical performance data and the vibration, acceleration and shock test results discussed indicate the feasibility of using the present generator for extending the useful life of satellites.

2002
Katz, Kurt. THERMOELECTRIC GENERATORS FOR THE CONVERSION OF SOLAR ENERGY TO PRODUCE ELECTRICAL AND MECHANICAL POWER. 30, illus., New York, United Nations, Apr. 10, 1961. (E/CONF. 35/S/12)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

This paper is restricted to the utilization of solar energy as the heat source and the conversion thereof to electrical energy by means of thermoelectric conversion (Seebeck-Peltier effect). A brief review of the equations and parameters of importance in predicting performance of a thermoelectric generator and the status of materials for this mode of energy conversion are presented.

2003
Kobayashi, Masatsugu. THERMOELECTRIC GENERATOR. 11p., New York, United Nations, Apr. 10, 1961. (E/CONF. 35/S/10)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

Utilization of some silicides of transition metals for the purpose of themoelectric generation is reported.

2004
Martin Co. Nuclear Division, Baltimore, Md. SNAP III-THERMOELECTRIC GENERATOR ENVIRONMENTAL TEST. vl.II, by L. W. Gross. 50p., Oct. 1959. (Rept. P-3101-II)

The thermoelectric generator operated for about 250 hr during the entire test program. The efficiency varied ~ 5% of the total performance during the vibration cycle, and remained relatively stable during the acceleration and shock tests. Recovery was complete in all cases. Oscillatory d-c superimposed on the d-c output of the generator was observed during the shock and vibration tests, and disappeared when the environmental forces were discontinued. The maximum d-c ripple was 7.4 millivolts rms in the y-Plane during the shock and vibration cycles. It was concluded that SNAP III thermoelectric generator No. 1G5 is reliable in environments simulating the WS-117 L vehicle.

2005
Meyer. A NEW WAY OF USING THE THERMOPILE. Elec. World 26:324, 1895.

A thermoelectric generator operates on a principle which eliminates a steady heat flow from one junction to another. Heat is applied for a short time to one set of junctions and then, by means of movable dampers, is applied to the other set of junctions. Direct or alternating voltage can be generated.

2006
Michel, R. NEW SOLAR THERMOELECTRIC GENERATORS - DESCRIPTION, RESULTS AND FUTURE PROSPECTS. 11p.,

illus., New York, United Nations, April 23, 1961. (E/CONF.35/S/55)

History of development, principle of operation, structure, performance, and prospects for small flat solar generators tested at Manosque and Toulon, France and Colomb Bechar, Africa.

2007
Motto, J. W., Jr. USING THE HALL GENERATOR, A NEW CONTROL AND INSTRUMENTATION COMPONENT. Part II. Automatic Contr. 15:24-29, figs., Jly. 1961.

Characteristics and application data for the Hall generator is presented which is applicable to a wide variety of electrical and electromechanical functions. This concluding article presents temperature effects on parameters and typical applications techniques.

2008
NEW PROGRAM SEEKING ADVANCES IN THERMIONICS. Electron. 34: 12, May 5, 1961.

A joint undertaking is referred to, in brief, which seeks to develop low-cost thermoelectric couples to provide power for control of motors and fans on gas furnaces.

2009
POWERFUL THERMOELECTRIC GENERATOR. Design News 15:133, June 20, 1960.

Powerful thermoelectric generator delivers five kw by direct conversion, without major moving parts, of heat into electricity. It is claimed to be 50 times more powerful than any previously described thermoelectric power plant.

Article with same title appears in Financial Times, p. 11, June 26, 1959.

2010
Rand Corp., Santa Monica, Calif. THERMOELECTRIC POWERPLANTS UTILIZING CONTAINED NUCLEAR EXPLOSIONS, by G. A. Hoffman. 36p., Feb. 18, 1960. (Rept. RM-2490-1) (Contract AF49(638)-700) (AD 256 812)

This study is an attempt at defining the problem of stationary thermoelectric powerplants that would utilize the thermal energy released by detonating nuclear devices in a closed cavity, surrounded by a heat exchanger. Major obstacles are detailed with the suggestion that none of them are insurmountable. A more thorough study is recommended.

2011
Sampson, R. L. THERMOELECTRIC GENERATOR EFFICIENCY. In International Heat Transfer Conference, University of Colorado, 1961. Papers, Part I, p. 86-92, New York, American Society of Mechanical Engineers, 1961.

The thermal efficiency of a simple two-element thermoelectric generator is derived from the basic equation governing the flow of heat in the elements. The analysis is restricted to one-dimensional flow of heat and electric charge.

2012
Shields, J. THERMOELECTRIC GENERATION. Brit. Power Eng. 2:26-30, Jan. 1961.

Considers the efficiency of the thermoelectric generation and indicates that values above 10% are at present unattainable owing to material limitations. The thermoelectric properties of some materials are reviewed. (Fuel Abs. & Current Titles 2:1098, Feb. 1961)

2013
SPACE THERMOELECTRIC UNIT USES SOLAR ENERGY. Electronic. 34:77, Jan. 20, 1961.

Refers briefly to a solar-energy thermionic conversion device consisting of semiconductor elements sandwiched between light-weight metallic sheets. Heat from the

sun is collected by one metallic sheet and conducted through it to the semiconductor element. Heat energy not converted to electrical energy by the element is passed to the opposite sheet from which it is radiated into space.

2014
Texas Instruments, Inc., Dallas, Tex. PELTIER COOLING OF SEMICONDUCTOR COMPONENTS. 2p., Apr. 15, 1961. (Mon. Prog. Rept. 10) (Contract NObsr-81204) (AD-255 008)

An evaluation was made of a Peltier cooler designed for a 2N1038 transistor which dissipates 20 watts of power at room temperature and is derated linearly to 0 watts at 100°C.

2015
Texas Instruments, Inc., Dallas, Tex. PELTIER COOLING OF SEMICONDUCTOR COMPONENTS. Final Technical Report. 48p., June 15, 1961. (Contract NObsr-81204) (AD-259106)

Design of a thermoelectric device for cooling two semiconductor components.

2016
THERMOELECTRIC ELEMENTS. Prod. Design 14:13, Dec. 1959.

Thermoelectric generators using lead telluride elements are reported to have a 6% efficiency. Prototype elements are said to be available for pilot plant use of experimental work. Waste heat possibilities are mentioned. Thermoelectric generators are said to have operated successfully at temperatures of 1100° F for several years. Calculated thermal efficiency at matched load conditions for elements under a temperature differential of 1000° F is 7.85%.

2017
THERMOELECTRIC GENERATOR. ISOTHERMAL HOT ROD KEY TO OPTIMUM PERFORMANCE. Electromech. Design 5:14-15, illus., Aug. 1961.

Problems in designing thermoelectric generators can be divided into three main categories: structural considerations, electrical and thermal insulation, and thermal contact and heat rejection. P. E. Pityk and T. M. Corry of Westinghouse report on how they handled these problems in the design of their hot rod thermoelectric generator.

2018
THERMOELECTRIC GENERATOR PUT ON SALE BY U.K. FIRM. Chem. Eng. 67:62, Feb. 8, 1960.

International Technical Developments Co., Colnbrook, Bucks., are marketing a thermoelectric device capable of generating 2 to 3 W of power and enough d.c current to operate a portable radio. The unit was developed by the Leningrad Institute in the Soviet Union where it has been in commercial production for the last two years. A brief description is given. (Fuel Abs. Current Titles 1:1002, June 1960)

2019
THERMOELECTRIC GENERATOR TESTED FOR CATHODIC PROTECTION. Gas 37:66, illus., Apr. 1961.

A brief report on field tests by the Northern Illinois Gas Co. of the feasibility of cathodic protection of gas mains by means of a 10-watt thermoelectric generator. A "perfect job" in combating corrosion has been accomplished during seven months of use. Operating costs and the durability factor are mentioned.

2020
THERMOELECTRIC GENERATORS BURN ANY TYPE OF FUEL. Steel 148:66, Jan. 23, 1961.

General information article relative to generators in ratings of 5, 10, 50 and 100 watts made available for commercial and industrial applications.

2021
Thiele, A. W. and Coombs, M. G. SNAP THERMOELECTRIC SYSTEMS. In Snyder, N. W. ed. Space Power Systems, p. 333-340, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

The SNAP-10, a 300-watt system considered here, consists of a reactor heat source, a thermoelectric converter, and a radiator for heat rejection.

Also issued as ARS Paper 1330-60.

2022
TURN ON GAS—GET ELECTRICITY: THERMOELECTRIC GENERATORS CAN SUPPLY POWER FROM GAS HEAT. Chem. Eng. 68:86, illus., Mar. 6, 1961.

The Westinghouse generator referred to is suited for applications in remote areas where electricity is non-existent, but gasoline, natural gas or propane can be supplied. Connected to a gas source, for instance, the generator, using the thermoelectric principles, can produce 5, 10, 50 or 100 w.

2023
Wainer, E. INVESTIGATIONS OF DIRECT GENERATION OF ELECTRICITY FROM HEAT UNDERWAY. Instr. Soc. Am. J. 5:72, Jly. 1958.

Dr. Eugene Wainer, Director of Research of Horizon's, Inc., comments on the future of nuclear fission and solar energy as sources of heat for thermoelectric generation in this news item.

2024
Webb. E. L. R. THERMOELECTRICITY. NRC Canada. Radio Elec. Eng. Div. Bull. 11:7-8, Jan/Mar. 1961.

A project has been started, the immediate aim of which is to construct a few 10-watt generators suitable for maintaining the charge of a single-cell storage battery. The thermoelectric material selected was of the bismuth telluride type customarily considered to be refrigerator material, but which may be used in moderate temperature generator applications.

2025
WESTINGHOUSE HAS NEW GENERATOR. Chem. & Eng. News 38:47-48, Mar. 28, 1960.

Westinghouse is testing a new generator that produces an electric current by pushing a hot, ionized gas through a magnetic field at high speed. The unit has already operated in kilowatt range for sustained periods.

2026
Westinghouse Electric Corp. New Products Laboratories, Cheswick, Pa. 5-KW THERMOELECTRIC GENERATOR. Final Report, by M. D. Fisher, J. C. Kastovich and W. C. Moreland. 9p., 56 figs., Mar. 1961. (Contract Nobs-77093)

The construction of the 5-kw thermoelectric generator which was shipped to the U.S. Naval Experiment Station on May 19, 1960, was the initial attempt at solving material selection, fabrication, assembly, operating and control problems of a large size generator. Details and many illustrations are included in this final report.

2. Heat Pumps (Refrigeration—Temperature Control)

2027
Ambrose, E. R. HEAT PUMP SYSTEM EMPLOYING STORAGE AND USING AUXILIARY HEAT. In Space Heating with Solar Energy, p. 148-151, Cambridge, Massachusetts Institute of Technology, 1954.

Describes operating cycle, storage systems, and solar energy as heat source.

2028
Amerio, A. UN NUOVO SOLARIGRAFO. (A NEW

PYRHELIOMETER). Nuovo Cimento 16:53-58, Feb. 1939.

In Italian. New thermoelectric solar energy measuring device with recorder is described and illustrated.

2029
Andersen, J. R. THERMOELECTRIC AIR CONDITIONER FOR SUBMARINES. RCA Rev. 22:292-304, figs., June 1961.

The results thus far obtained in a program of design and experimental development of a thermoelectric air conditioner for submarines are reviewed. The basic design concept is discussed in terms of performance, pressurization, sea-water corrosion, and simplicity. A working theory which expresses the performance of a "real" thermoelectric refrigeration machine leads to a discussion of the design parameters for such a machine. The results of design optimization studies are then displayed showing, specifically, the size of the machine and the weight of thermoelectric material required as a function of maximum coefficient of performance for a variety of thermopile configurations. The final design, based on these considerations, is presented and its expected performance is discussed. Experimental performance data obtained from a one-ton model, constructed according to this design, is discussed and compared with predicted performance, and some difficulties in implementing the design concepts are mentioned. It is concluded that large-capacity, compact thermoelectric air conditioners for special applications are feasible at the present state of the thermoelectric art.

2030
Aoki, Masaharu and Suge, Yoshio. THERMOELECTRIC COOLING BY USE OF BISMUTH TELLURIDE THERMOJUNCTIONS. V. THERMOELECTRIC MATERIALS. Oyo Butsuri 29:363-370, 1960.

In Japanese. Abs. in Chem. Abs. 54:20384, 1960.

2031
AN AUTOMATIC DEWPOINT MEASURING EQUIPMENT UTILIZING PELTIER-COOLING. ETZ 22B:546, Oct. 31, 1960.

In German. The Peltier effect, which involves the liberation of absorption of heat at the junction of two dissimilar conductors when a current flows across the junction, causes a temperature drop of 30° C at 3 A and 45° C at 7 A current in a junction combining 80% Bi_2Te_3 + 20% Bi_2Se_3 + 0.02% AgI with 60% Sb_2Te_3 + 40% Bi_2Te_3 + 0.05% Ag. The polished surface of a silver plate attached to the semiconductors reflects the light of a light-source to a photoconductive cell which in turn regulates the current through the junction. The Peltier effect reduces the temperature of the mirror until condensation reduces the reflected light and a servo system controlled by the light re-adjusts the current. Balance is obtained at the dewpoint temperature with an accuracy better than 0.5° C. (Sci. Abs. 64B:1767, 1961)

2032
Bernor, J. and Jarry, C. ELECTROTHERMIE. (ELECTRICAL HEATING). 208p., Paris, Librairie Armand Colin, 1961.

In French. Includes a chapter on thermoelectric refrigeration.

2033
Borg-Warner Corp. Roy C. Ingersoll Research Center, Des Plaines, Ill. SUBMARINE FOOD STORAGE PROJECT, by B. M. Jaremus, R. L. Juehner, and W. Scholten. 92p., Sept. 1, 1960. (Rept. 3230, Phase I) (Contract Nobs-78356) (AD 263 001)

A preliminary study of the application of thermoelectricity to food storage refrigeration is presented.

2034
Burshtein, A. I. ON THE ECONOMY OF CASCADE COOLING THERMOGENERATORS. Fiz. Tverdogo Tela 2:2505-2508, Oct. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2232-2235, Apr. 1961.

The overall efficiency is calculated on the assumption that the quality characteristics of a thermocouple is independent of temperature. The efficiencies for one and for an infinite number of cascades are little different over an overall temperature ratio varying from 1.2 to 3.0.

2035
Burshtein, A. I. ON THE EFFICIENCY OF CASCADE COOLING THERMOBATTERIES. Fiz. Tverdogo Tela 2:2509-2516, Oct. 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:2236-2243, Apr. 1961.

The coefficient of performance and heat extracted are calculated as functions of the overall temperature ratio and the number of cascades. The former increases little with the number of cascades beyond two, while for the important temperatures the latter decreases with increasing number of cascades. Although each specific case requires analysis, it is not useful to employ more than three cascades.

2036
CITES NEW USES FOR THERMOELECTRICS. Steel 148:75, Feb. 20, 1961.

Present thermoelectric materials are good enough to make feasible a variety of temperature regulating and cooling devices, claims Irving I. Sochard of the Army's Diamond Ordnance Fuze Laboratories.

2037
COUPLES THAT COOL DEVELOPED IN BRITAIN. Prod. Eng. 31:8, Feb. 15, 1960.

A very brief article which includes an illustration of a thermoelectric element designed by GE, Ltd, incorporating 182 junctions. Materails under test are bismuth and antimony tellurides, bismuth selenide and sulfide.

2038
CUT-RATE THERMOELECTRICS CLAIMED BY JAPANESE. Prod. Eng. 32:6, illus., Jly. 3, 1961.

"Thermoelectric elements for panel cooling-systems, refrigerators, and 'thermopacs,' for less than $3 a pair. That's the claim of Sanyo Electric. And, the Japanese company says, when its new Osaka plant is finished next month, it will be able to produce about a million a year.

"These are bismuth telluride elements, combined into modules containing 10 pairs each. The refrigerator uses 16 such models; the thermopac, 12; the panel systems, 88. Based on Sanyo's present prices, this means thermoelement cost for the refrigerator totals about $450. That's not cheap; but, Sanyo says proudly, it's 25% below the cost for any other Japanese manufacturer. It's considerably below U.S. costs too. A recent price list by one U.S. supplier shows a rock-bottom price for a 16-element module of about $70, or $700 for a comparable refrigeration system." Entire item quoted.

2039
Diamond Ordnance Fuze Laboratories, Washington, D.C. COOLING LARGE ELECTRONIC PACKAGES, by J. G. Moorhead. 39p., Jan. 1961. (Tech. Rept. 882) (AD-251 342) (PB 171 540)

In an investigation of methods of cooling densely packed electronics packages, three cooling systems are compared. It is shown that: (a) a system employing thermoelectric cooling elements which extend from the package walls to the interior is useless except for very small packages; (b) that the package structure can cool packages of considerable size by thermal conduction through the structure members when the whole package is effectively designed; and (c) the size limits of packages cooled by thermal conduction can be significantly increased by placing auxiliary thermoelectric refrigerator

units in the package walls. An equation is derived for the temperatures in packages cooled by thermal conduction alone on the assumption of a homogeneous arrangement of highly microminiaturized package components. The use of the equation for estimating package-size limitations for satisfactory cooling by conduction alone is illustrated by examples of package cooling systems.

2040
Diamond Ordnance Fuze Laboratories, Washington, D. C. DESIGN AND CONSTRUCTION OF A PELTIER TEMPERATURE-CONTROL DEVICE, by I. I. Sochard. 39p., Apr. 24, 1961. (Tech. Rept. 896) (AD 257 333)

A study has been made of the problems of design and construction of Peltier temperature-control devices for use with Ordnance electronics. The principal features sought were: (1) compatibility with conventional power supplies, particularly single-cell electrochemical systems; (2) techniques of assembly that are versatile with respect to physical configurations; and (3) techniques of assembly that are readily adaptable to production.

A device for cooling has been designed, built, and tested that operates from a supply voltage of 1.5 to 2.0 v at input powers up to about 6 w. Eighteen thermoelectric couples were connected in series electrically and in parallel thermally.

By using jigs that are adaptable to quantity production, all 72 solder joints connecting the elements in series and to the structural materials were made in two operations.

2041
Diamond Ordnance Fuze Laboratories, Washington, D. C. PERFORMANCE LIMITS OF MULTISTAGE THERMOELECTRIC DEVICES, by I. I. Sochard. 13p., illus., Jly. 28, 1961. (Tech. Rept. 947)

A simplified method of calculating the performance limits of multistage thermoelectric devices is presented and the results obtained for the multistage devices are compared with those for single-stage devices. The results indicate that at present there is little advantage in using more than one stage in a thermoelectric generator. In the case of a thermoelectric refrigerator, however, a small feasible multistage device should be able to produce temperature reduction about twice as great as that obtainable with a single-stage device. Using presently available materials, this corresponds to a maximum temperature reduction approximately 135° C for the multistage device. It is also shown that even if materials are substantially improved, it will probably never be feasible to construct a thermoelectric refrigerator that can cool to cryogenic temperatures while operating from room temperature ambient.

2042
Dorr, W. (FRIGISTORS - THERMOPAIRS CONSISTING OF SEMICONDUCTOR MATERIAL FOR THE USE AS COOLER AND HEATING PUMPS) Elektron. Rund. 15:110-111, Mar. 1961.

In German. Research in the field of semiconductors has lately resulted in the development of bismuth-tellurium compounds having an extraordinary Peltier effect. The efficiency of coolers made of such compounds favorably compares with that of conventional refrigerators. Small dimensions of these so-called frigistors allow for the application of frigistors in fields where technical or cost considerations precluded the use of known cooling methods.

2043
Forsberg, Nils. MEASUREMENT OF THERMOELECTRIC POWER OF DIFFERENT ALLOYS. DIFFERENT COMBINATIONS FOR PELTIER COOLING JUNCTIONS. Kyltek. Tid. 11:53, 1952.

In Swedish. Not examined.

This is said to be a "comprehensive survey on the present state of our knowledge concerning thermoelectric cooling." For further details see article entitled Thermoelectric

Cooling, Review of Developments. Refrig. Eng. 61:878-879, Aug. 1953.

2044
Fortier, J. R. and Thompson, C. S. COOLING TRANSISTORS WITH THERMOELECTRIC ELEMENTS. Electron. 34:43-45, Mar. 31, 1961.

Thermoelectric coolers can be used for local cooling of hot transistors. Results of using these elements on transistors operated below and above their maximum rated junction temperatures are discussed.

2045
Fournet, M. LES PLAQUETTES REFRIGERANTES PAR EFFET PELTIER. (PLATES FOR COOLING BY THE PELTIER EFFECT). Onde Élec. 41:140-141, Feb. 1961.

In French. The plates briefly described are constructed with semiconductor thermoelements and are suitable for use in thermostatically controlled or localized freezing devices. (Instr. Abs. 16:4099, 1961)

2046
Gehlhoff, P. IMPROVED THEORY OF THERMOELECTRIC REFRIGERATION. Refrig. Eng. 58:1079, Nov. 1950.

Review of an article by Gehlhoff, Justi and Kohler (Abh. Braunschw. Wissen. Gesell. 2:149-164, 1950), stating that "the authors have now investigated whether a conical shape of the thermocouple branches is advantageous for refrigeration... Any dependence on shape of the branches has not been found."

2047
Gelbtuch, A. and Macphee, C. A. A. DESIGN CURVES AID PROPER UTILIZATION OF THERMOELECTRIC DEVICES. Can. Electron. Eng. 5:32-35, Feb. 1961.

Diagrams are given from which the performance data of Frigistors under various conditions can be obtained. Their use is illustrated by two examples: a refrigerated box and a vacuum pump baffle. (Semiconductor & Solid-State Bib. 4:44, Aug. 1961)

2048
Goodyear Atomic Corp., Portsmouth, Ohio. THERMOELECTRIC REFRIGERATOR FOR THE LINE RECORDER MASS SPECTROMETER (THEORETICAL DESIGN), by P. I. David. 25p., Nov. 14, 1960. (Rept. 365)

A theoretical discussion of a thermoelectric device for cooling the line recorder chemical trap is presented. For such a device semiconductor materials are employed to do the heat pumping. The materials considered are lead telluride (PbTe) and bismuth telluride (Bi_2Te_3). Also included are a brief treatment of semiconductor thermoelectric theory and design calculations for a single-stage and a two-stage refrigerator. At present a lead telluride unit appears impractical, and a bismuth telluride unit appears too costly. A recommendation is made to delay the construction of a thermoelectrically cooled chemical trap. Meanwhile, a bismuth telluride refrigeration unit should be perfected for other uses. (Nuclear Sci. Abs. 15:11161, 1961)

2049
HEAT, COLD COME FROM SAME SOURCE IN NEW DEVICE. Elec. Eng. 80:395-396, May 1961.

A device smaller than a paper clip is described. It can produce either heat or cold on demand, and is so efficient that it can freeze or boil a drop of water on power from two flashlight batteries. The principle of thermoelectric cooling is employed.

2050
HEAT, COLD FROM SAME THERMOELECTRIC SOURCE. Plant 23:51, illus., Apr. 1961.

A very brief item mentioning a tiny thermoelectric device which "is so efficient it can freeze or boil a drop

of water on power from two flashlight batteries, with a flip of a switch." Suggested uses vary from heating a space ship cabin to operating an instant-defrost refrigerator.

2051
HUGHES IR PELTIER COOLER OPERATES ON LOW CURRENT. Electron. Design 9:10-11, Feb. 15, 1961.

A thermoelectric heat-cooling device said to require 1/10th the current of previous Peltier units is reported by Hughes Aircraft Company.

Also in Electron. 34:9, Feb. 10, 1961.

2052
Jepson, R. M. and Nessick, G. G. DESIGNING LOW-CURRENT THERMOELECTRIC COOLERS. Electron. 34:58-50, figs., Apr. 21, 1961.

Recent advances in thermoelectric material technology have made Peltier-effect coolers practical. A disadvantage of most coolers has been the requirement for large currents (15-25 amp) at low voltage (0.1-0.5 v); however, by reducing the cross sectional area of the thermoelectric elements and connecting many small elements in series, coolers can be operated at currents of 0.5 to 3 amp at 3 volts or less.

2053
Keyes, R. W. LOW TEMPERATURE PELTIER COOLING. In Heikes, R. R. and Ure, R. W., Jr. Thermoelectricity: Science and Engineering, p.389-404, New York, Interscience Publishers, 1961.

The feasibility is explored of producing temperatures less than 77°K by thermoelectric cooling of the type which has proved successful in the range of temperatures around 300°K. Emphasis is on the principles involved, and specific materials are mentioned only for purposes of illustration.

2054
Kikuchi, M. and Iizuka, T. THE EXPERIMENT OF THE THERMOELECTRIC REFRIGERATION BY Bi_2Te_3. Electrotech. Lab. Japan. Bull. (Tokyo) 23:671-677, Sept. 1959.

In Japanese. Cooling effects of an experimental refrigerator using both n- and p-type Bi_2Te_3 are reported. Materials used had the following properties: p-type: $-p = 1.30 \times 10^{-3}$ ohm cm and $n = +127\ \mu V \cdot deg^{-1}$; n-type: $-p = 1.23 \times 10^{-3}$ ohm cm and $n = -162\ \mu V \cdot deg^{-1}$, where p = electric resistivity and n = thermoelectric voltage. The temperature of the hot and cold junctions was measured in air as a function of applied current and voltage. A maximum temperature of 26° C at a mean temperature of 3° C was obtained with the cold junction lagged with cotton. (Sci. Abs. 64B:3838, 1961)

2055
Love, C. C., Jr. CRYOGENIC PROPELLANT STORAGE PARAMETERS ON MOON. 34p., New York American Astronautical Society. (Preprint 60-80)

A preliminary analysis of lunar heat loads and of methods for minimizing propellant boil-off loss due heat loads are presented. Parametric data on lunar heat transfer factors (e.g. solar radiation, moonshine) and insulation methods are included. Methods for negating boil-off losses including thermoelectric cooling and propellant solidification are examined. Hydrogen storage time information is presented and the advantages gained from special handling, location, and design techniques are mentioned. (Index Aero. 17:112, Feb. 1961)

2056
LOW-COST THERMOELECTRIC SPOT COOLER FOR SALE - OFF THE SHELF. Electron. Design 9:78-79, Feb. 15, 1961.

A small cooler which can pump as much as 2 thermal watts is manufactured by Minnesota Mining & Manufacturing Company. It can be used to cool hot spots in electronic equipment.

2057
Macphee, C. A. A. THE DEVELOPMENT OF THERMOELECTRIC MATERIALS FOR REFRIGERATION. Can. Electron. Eng. 5:36,54, Feb. 1961.

Five months after the Needco laboratory buildings were completed, materials suitable for thermoelectric cooling application were produced which equalled the currently accepted standards of the industry. (Semiconductor & Solid-State Bib. 4:44, Aug. 1961)

2058
Marlow, Raymond. PELTIER COOLING OF ELECTRICAL COMPONENTS IN TELEMETERING PACKAGES. ARS J. 31:263-265, Feb. 1961.

Application of Peltier cooling to obtain an adequate thermal environment inside the telemetry package of missiles and satellites.

2059
Morgan, R. A. THE HEAT PUMP. In Daniels, Farrington and Duffie, J. A., eds. Solar Energy Research, p. 69-73, Madison, University of Wisconsin Press, 1955.

Operating details and examples are given.

2060
Nagata, Minoru and Abe, Zenemon. THERMOELECTRIC ELEMENT FOR CIRCUIT COOLING. Electronic. 34:54-55, illus., Oct. 13, 1961.

Constant temperature chamber operates below ambient, provides a favorable stabilizing environment for sensitive direct-coupled circuits. Noise and drift of semiconductor circuits are reduced.

2061
Nasledov, D. N. SEMICONDUCTORS. Poluprovodniki p. 22, 23, 27, 29, 30, 42, 44, 1959.

In Russian. Trans. of selected parts by Aerospace Technical Intelligence Center, Wright-Patterson AFB, Ohio, no. MCL-500. 4p., Nov. 2, 1960. (AD-255 388) Order from OTS or SLA.

A discussion is presented on semiconductors with respect to thermoelectrical triode cooling, among other topics.

2062
Naval Ordnance Test Station, Inyokern, Calif. TESTS OF A NORTRONICS PELTIER COOLER, by V. A. Ereaux. 7 p., Oct. 19, 1960. (Interim Devlpmt. Rept. 1107)

A report of results of tests at several different ambient temperatures and with various heat-loads on the cold junction.

2063
NEW APPROACH TO FABRICATION: THERMOELECTRIC HEATING AND COOLING. Arch. Forum 106:112-114, Jan. 1957.

A non-technical article on the use of Peltier effect by RCA under the direction of N. E. Lindenblad, to construct room panels for electronic air conditioning and heating. ZnSb and PbTe are mentioned as possible semiconductors for such purposes, although not the best. BiSb is the semiconductor in one of the accompanying diagrams.

2064
NEW INTEREST IN THERMOELECTRICS. Power 104:57-60, Jan. 1960.

Review of phenomenon of thermoelectricity and its utilization for generation of power (Seebeck effect) and for refrigeration (Peltier effect). Some research efforts by Westinghouse, RCA, Whirlpool, and General Electric are discussed; report on Russian developments indicates

comparable progress. (Eng. Index p. 1500, 1960)

2065
NEW MATERIALS MAKE HIT; HOT-ROCK INSULATION, NEW THERMOELECTRIC JUNCTION MATERIALS. Electron. 31:8, 12, Nov. 7, 1958.

In this new item on Westinghouse's work with mixed valence oxides, intermetallics, and semiconductors, there is mention of an electroluminescent panel whose thermoelectric elements can create a range of surface temperatures from 40° to 130°F. The thermoelectric junctions utilized are described as "bimetallic junctions using special alloys."

2066
[NEW PRODUCTS] . THERMOELECTRIC COOLERS. Westinghouse Electric Corp., Semiconduction Division, Solid State Abs. 1:6615, 1960.

"Component-matched (i.e. with dimensions to fit specific components) thermoelectric coolers for cooling electronic devices are announced. Units can be supplied complete with fins or other heat sinks. The coolers can be used with transistors, infrared detectors, laboratory and portable medical equipment and for controlling temperatures of solids, liquids, and gases." Entire item quoted.

2067
New York University. College of Engineering, New York. RESEARCH ON PELTIER EFFECT COOLING, by E. Miller, I. Cadoff, and M. Telkes. 4 issues, 1954, 1955. (Quart. Prog. Repts. 1, 2, 3, 4) (AD-46 617, AD-62 269, AD-79 904) Contract DA36-039-sc-64422)

An investigation is described of Peltier cooling of semiconductors and semiconductor devices, including the preparation of thermocouples and the construction of such special measuring equipment as required.

2068
New York University. College of Engineering, New York, N. Y. RESEARCH ON PELTIER EFFECT COOLING, by E. Miller, et al. 3 issues, Apr., Oct. 1956, Jan. 1957. (Quart. Prog. Rept. 1, 3, and Final) (AD-94 211, AD-113 553, AD-124 909)

An investigation is reported of the Peltier effect cooling of semiconductors and semiconductor devices.

2069
O'Brien, B. J. and Wallace, C. S. ETTINGSHAUSEN EFFECT AND THERMOMAGNETIC COOLING. J. Appl. Phys. 29:1010-1012, Jly. 1958.

Possible use of Ettingshausen effect in refrigeration; phenomenological similarity of this cooling effect with cooling by cascade of Peltier couples is treated. Theoretical expressions for maximum cooling that is possible with Ettingshausen effect; it is shown that optimum shape of cooling element is exponential of given form; experiments with bismuth alloys give cooling of about 0.25°C. (Eng. Index 1958)

2070
O'Connor, J. R. THE USE OF THERMOELECTRIC EFFECTS DURING CRYSTAL GROWTH. Electrochem. Soc. J. 108:713-715, figs., Jly. 1961.

This paper considers only the use of Peltier cooling to increase the steady-state rate of crystallization V cm^3 sec^{-1} of a semiconductor growing from a melt.

2071
Parrott, J. E. INTERPRETATION OF STATIONARY AND TRANSIENT BEHAVIOR OF REFRIGERATING THERMOCOUPLES. Solid-State Electron. 1:135-143, May 1960.

Theory in improved form takes Thomson effect, temperature variation of electrical resistance and surface heat transfer into account. It is shown that considerable errors can arise from use of inappropriate approximate expressions, both in stationary state and in calculation of time constants of transient.

2072
PELTIER COOLING OF HOTSPOTS. Electromech. Design 5:32-33, illus., Aug. 1961.

Summary of a paper presented at the 16th Annual National Electronics Conference, in which P. S. Gage compared the effectiveness of reported thermoelectric materials to ordinary heat conductors in removing heat from hotspots in compact equipment.

2073
PELTIER EFFECT. Tele-Tech & Electron. Indus. 14:13, 110, Mar. 1955.

This is a news item in which RCA's electronic cooling system is mentioned and the Peltier effect upon which it is based is briefly discussed.

2074
Penrod, E. B. THEORETICAL ANALYSIS OF PELTIER REFRIGERATION. 19 p., New York, American Society of Mechanical Engineers, 1959. (Paper 59-A 266)

Unit considered consists of single thermocouple connected to d-c power supply, and is used in appliance like hostess cart or bottle warmer. Differential equation derived connects four heat power terms of thermocouple arms; in two particular solutions arms are considered to be thermally insulated. Thomson effect is neglected in one case and included in the other; a series of useful equations is derived. (Eng. Index p. 1222, 1960)

2075
Poslawski, R. P. THERMOELECTRIC COOLING IMPROVES BAFFLES FOR VACUUM PUMPS AND SYSTEM. Can. Electron. Eng. 5:37-39, Feb. 1961.

A thermoelectric baffle has been developed for use as a refrigeration element in vacuum pumping systems which can operate down to temperatures that are adequate for the condensation of commonly used diffusion pump fluids. (Semiconductor & Solid-State Bib. 4:44, Aug. 1961)

2076
Radio Corp of America. Defense Electronics Products, Camden, N.J. THERMOELECTRIC AIR CONDITIONER FOR SUBMARINES. Final Report, Phase I. 1/2 in. thick, Jan. 15, 1960. (Contract NObsr-77123)

Design, performance, and material evaluation are detailed.

2077
RCA ELECTRONIC REFRIGERATOR. Refrig. Eng. 65:59, Jan. 1957.

A very brief statement is given relative to a refrigerator based in new knowledge concerning an old principle - the Peltier effect.

2078
Stil'bans, L. S., Ioradnishvili, E. K., and Stavitskaya, T. S. THERMOELECTRIC REFRIGERATION. Akad. Nauk. SSSR. Ser. Fiz. Izvest. 20:81-88, 1956.

In Russian. The theory of refrigeration using the Peltier effect in semiconductors is summarized and factors influencing choice of materials are discussed. Graphs showing experimental agreement with theory for the case of PbTe are presented. The maximum temperature difference observed was 48°C (from +34 to -14°C). This could be improved by the use of two or three couples in cascade, the best figure quoted being 70°C (+25 to -45°C) for three cascades. In a practical refrigerator, a 10 litre volume was maintained at 4°C in an ambient of 27°C.

2079
Stubstad, W. R. THE APPLICATION OF THERMOELECTRIC COOLING TO ELECTRONIC EQUIPMENT. In IRE International Convention Record 1961, Part 6, p. 38-46, New York, Institute of Radio Engineers, 1961.

Information is given on the thermal and mechanical evaluations of the spot cooler along with a discussion of the applications of spot cooling to electronic equipment.

2080
Stubstad, W. R. TEMPERATURE CONTROL WITH THERMOELECTRICS. Control Eng. 8:178-179, figs., Sept. 1961.

Thermoelectric device development has reached the point where specific engineering applications of Peltier heating and cooling are practical. Typical are the spot cooling of critical electronic components and the air conditioning of special enclosures. Beyond these, general purpose commercial and consumer applications will be feasible in the mid 1960's. The paper examines characteristic current units of use to control engineers, samples commercial equipment, and gages the potential of thermoelectrics.

2081
THERMOELECTRIC COOLING-REVIEW OF DEVELOPMENTS. Refrig. Eng. 61:878-879, Aug. 1953.

This is a review of several articles dating from the basic theoretical treatment of thermoelectric cooling by Altenkirch in 1911.

2082
THERMOELECTRIC COOLING UNIT. Engr. 210:809, Nov. 11, 1960.

Illustrates and briefly describes a cooling unit (BT. 4) consisting of four junctions of p-n bismuth telluride. Nominal rating 1W.

2083
THERMOELECTRIC REFRIGERATOR. Res. Appl. Indus. 13:242, June 1960.

GE has manufactured a prototype small thermoelectric refrigerator which can operate from a battery d.c. supply. It works on the principle of the Peltier effect - the production of cold at one junction, of a thermocouple and heat at the other when direct current passes. The idea has been developed to a practical stage by evolving efficient semiconductor thermocouples and forms of construction that provide adequate thermal isolation between the hot and cold sides of the junction. Each thermocouple operates at low voltage and 5-10 amp, cooling power being about 1/4 W. The drop of air temperature obtainable is 20-30°C.

2084
THERMOELECTRICITY HEATS UP: DEVICE THE SIZE OF A PAPER CLIP CAN FREEZE WATER. Chem. Eng. 68:98, illus., Mar. 20, 1961.

Brief reference is made (including illustration) to a thermoelectric device based on the Peltier effect, developed by Hughes Aircraft Co. Possible applications are said to range from constant-temperature maintenance in spaceships to instant-defrost refrigerators.

A few other recently developed thermoelectric units are also mentioned.

2085
THERMOELECTRICS MAY OPEN NEW SALES VISTAS. Elec. World 150:116, Jly. 21, 1958.

In this news item, Westinghouse promotes its commercial thermoelectric devices, such as the bottle-warmer-cooler and hostess cart.

2086
Tseng-shou, L. THE APPLICATION OF SEMICONDUCTOR REFRIGERATION. K'o-hsueh Hsin-wen (Sci. News) no. 29, p. 7-9, Sept. 21, 1959.

In Chinese. Trans. by Joint Publications Research Service, JPRS: 7727.

Various applications are briefly described such as temperature regulators for photosensitive resistors, slicing machines for frozen biological tissues, semiconductor vacuum pumps, humidity meters, and calibrators.

2087
U. S. Air Force. Rome Air Development Center, Griffiss Air Force Base, N. Y. CRYOGENIC THERMOELECTRIC COOLING, by J. E.

McCormick. 23 p., illus., May 1961. (Tech. Note 61-54) (AD 259770)

This report discusses the thermodynamics of thermoelectric cooling, describes a hypothetical thermoelectric device exhausting heat to a liquid nitrogen bath, discusses the limitations of such a device, and discusses the phenomena that may improve the performance of thermoelectric materials in the low temperature range.

2088
U. S. Army. Aberdeen Proving Ground. Ballistic Research Laboratories, Aberdeen, Md. DEVELOPMENT AND FLIGHT TEST OF A NEW POINT HYGROMETER UTILIZING THERMOELECTRIC (PELTIER) COOLING. HIGH ALTITUDE INSTRUMENTATION REPORT NO. IV, by G. A. Dulk. 27 p., Nov. 1960. (Memo. Rept. 1308) (AD-250 470) (PB 154 373)

A brief description of dew point hygrometer operation is given and Peltier effect theory is reviewed. Particular emphasis is placed on the construction of the instrument with the problems inherent in the utilization of thermoelectric materials. The flight test on a balloon is discussed and the test results presented and analyzed.

2089
Whirlpool Corp., Research Laboratories, St. Joseph, Mich. DESIGN OF A SPECIFIC PROTOTYPE, INCLUDING CONTROLS, OF A THERMOELECTRIC REFRIGERATING SYSTEM FOR USE ABOARD SUBMARINES, by D. C. Nichols, R. L. Eichhorn, et al. 4 issues, Feb. 5, Aug. 2, Sept. 27, Oct. 31, 1960. (Prog. Repts. 7, 13, 15, 16) (Contract Nobs-77128)

Details are given of progress in design and testing.

2090
Whirlpool Corp. Research Laboratories, St. Joseph, Mich. THERMOELECTRIC TEMPERATURE CONTROL IN AN/URQ-9 FREQUENCY STANDARD, by R. G. Sickert and A. F. Martz. 49 p., Jly. 28, 1961. (Interim Devlpmt. Rept. 1) (Contract NObsr-85314) (AD 260939)

Objectives of the contract are to develop a crystal chamber in which the internal temperature is maintained by thermoelectric cooling and joule heating and to incorporate this chamber into an AN/URQ-9 Frequency Standard, replacing the crystal oven assembly which is presently used.

This report summarizes an evaluation of five proposed methods for modifying the ovens.

3. Thermocouples

2091
Bundy, F. P. EFFECT OF PRESSURE ON EMF OF THERMOCOUPLES. J. Appl. Phys. 32:483-488, Mar. 1961.

"Pressure" thermal emf's have been measured for constantan, Pt, Ni, alumel, Pt 10% Rh, Cu, chromel, and Ni 18% Mo for a ΔT of 100°C over a pressure range 0 to 72 kbar. Corrections due to pressure for common thermocouples made of pairs of these metals have been deduced. A number of thermocouple pairs have been compared at temperatures up to 1200°C and pressures up to 58 kbar. Below 200 to 300° the deviations between them agree quite well with the absolute data on single metals taken at ΔT of 100°C. At higher temperatures the deviations diminish and generally reverse. It appears that the deviation δT of the readings of two thermocouples at a given pressure follow roughly the relationship $\delta T = A(P)\Delta T + B(P)\Delta T^2$, where ΔT is the temperature interval in the pressurized zone, A(P) and B(P) are functions of pressure (roughly linear), and B(P) is generally opposite in sign to A(P) and is large enough to dominate the A(P) term at higher ΔT's.

2092
Clark, R. B. and Hagel, W. C. HIGH-OUTPUT NOBLE-METAL THERMOCOUPLES AND MATCHING LEAD WIRE. In High Temperature Thermometry Seminar, October 1-2, 1959, Oak Ridge National Laboratory, p. 3-1-43. Oak Ridge, Tenn., Oak Ridge National Laboratory, Aug. 1960.

Representative thermoelectric emf curves show comparison of noble metals and chromel/alumel.

2093
Dahlberg, R. THE LIMITATIONS OF METHODS FOR MEASURING SMALL TEMPERATURE DIFFERENCES AND QUANTITIES OF HEAT, AND A DESCRIPTION OF A THEORY OF THE THERMONEEDLE. Z. Naturforsch. 10A:953-970, 1955.

The need for improved thermocouple units and the construction of the thermoneedle are discussed. The pertinent literature is reviewed. A theory is developed on the basis of the thermoelement as a heat engine and then as a measuring unit. Properties of 24 pairs of metals are listed.

2094
Denver Research Institute, Denver, Colo. TEST EQUIPMENT FOR AN EVALUATION OF ELECTROMAGNETIC RADIATION. Volume I. APPLICATION OF EVAPORATED THERMOCOUPLES TO DETECTION OF RF POWER IN BRIDGE WIRES OF ELECTRO-EXPLOSIVE DEVICES. Final Report, 15 March 1957 - 30 November 1960, by R. C. Amme, R. F. Calfee, et al. 95p., illus., Nov. 30, 1960. (Contract N123(60530)10049A) (AD-250 090)

A review of the development and a discussion of the present status of vacuum deposited thermocouples are given. Measurements of thermoelectric powers and resistivities of evaporated films are given as a function of age for various thicknesses. Also presented are the effects of heat on film resistances and thermoelectric powers and studies of alumel films.

2095
Ehringer, H. ON THE LIFETIME OF PtRh THERMOCOUPLES. Metall. 8:596-598, 1954.

In German. NRL Trans. 863.

Experiments are described which give a picture of the sensitivity of the thermoelectric potential of various PtRh alloys concerning impurities which are absorbed preferably from the armor ceramic.

2096
General Electric Co., Syracus N. Y. RESEARCH AND DEVELOPMENT ON THERMOCOUPLE ENERGY CONVERTERS, Phase II, by W. J. van der Grinten. 27 p., Aug. 15, 1961. (Quart. Prog. Rept. 1) (Contract DA 30-069-501-ord-3294)

Attention has been focused on fabrication and measurements aspects of thermoelectric lead telluride cells. In conjunction with a brazed seal to be fabricated later, a new simple casting technique for the filling of elements has been successfully developed. Subject to experimental verification of electrical output values under prescribed operating conditions, this new filling technique promises to yield excellent n-type elements.

2097
General Electric Co. Aircraft Nuclear Propulsion Department, Cincinnati, Ohio. THERMOELECTRIC STABILITY OF Pt-Rh THERMOCOUPLES, by R. J. Freeman. 127p., Dec. 2, 1960. (Milestone No. 1 Report) (TID 11751) (Contracts AF33 (600)-38062, and AT(11-1)-171)

Pt-Rh thermocouples were tested under continuous and temperature cycling conditions. Noble-metal-sheathed thermocouples were found to be mechanically reliable in the temperature range of 2500 to 2600°F for 542 hr and to withstand 1,315 thermal cycles with thermal shock times of 40 sec through 2500 to 1000°F range. However, the thermoelectric stability of sheathed thermocouples was poor due to volatilization of Rh and Pt. One

configuration (Duax) shows promise of maintaining the required stability. (Nuclear Sci. Abs. 15: 19979, 1961)

2098
Haase, R. and Schönert, H. INVESTIGATIONS ON THE THERMOCOUPLES. IV. MEASUREMENTS. Z. Physik. Chem. (Frankfurt) 25: 193-204, 1960.

In German. For abstract see Chem. Abs. 55:6210, Apr. 31, 1961.

2099
Haase, R. and Sauermann, P. F. INVESTIGATIONS ON THERMOCOUPLES. Z. Physik. Chem. 27:42-47, 1961.

In German. Electrolytic thermocells containing Ag/AgCl electrodes and aqueous chloride solutions are discussed. A relation between the thermoelectric force of an electrolytic thermocell and the thermoforces of thermocouples was deduced and tested experimentally.

2100
High Temperature Thermometry Seminar. PROCEEDINGS .... Oak Ridge National Laboratory, October 1-2, 1959. 171p., figs., Oak Ridge, Tenn., Oak Ridge National Laboratory, Aug. 1960.

For analysis of contents see under the following authors: Clark, R. B.; Freeman, R. J.; Johannessen, H. G.; Kuether, F. W.; and Thelke, N. R.

2101
Johannessen, H. G. RELIABILITY ASSURANCE IN SHEATHED THERMOCOUPLES FOR NUCLEAR REACTORS. In High Temperature Thermometry Seminar, October 1-2, 1959, Oak Ridge National Laboratory, p. 95-99, Oak Ridge, Tenn, Oak Ridge National Laboratory, Aug. 1960.

Thermoelectric reliability is discussed in accordance with dependency on two factors: (1) a sound thermal junction; and (2) a proper, stable thermal emf output.

2102
Kaganov, M. A. THERMOELECTRIC MEASUREMENT OF TEMPERATURE DIFFERENCES IN CONDUCTIVE SOLIDS. Pribory i Tekh Eksp. no. 1, p. 145, Jan/Feb. 1958.

In Russian. Describes a simple scheme for direct measurement of small temperature differences in electrical conductors using two thermocouples and a bridge circuit. The circuit avoids the necessity for insulating one of the thermocouple working junctions, which is a potential source of error on the usual method where a differential thermocouple is used.

2103
Kennedy, G. C. and Newton, R. C. THE EFFECT OF PRESSURE ON THE ELECTROMOTIVE FORCE OF A PLATINUM-BISMUTH THERMOCOUPLE. J. Geophys. Res. 66:1491-1493, diags., May 1961.

The emf of a platinum-bismuth thermocouple changes discontinuously as the bismuth undergoes various polymorphic transitions at high pressures. The emf of a platinum-bismuth I thermocouple is approximately + 10 mmv/°C at 30°C. The emf of a platinum-bismuth II thermocouple is approximately -30 mmv/°C. The emf of a platinum-bismuth III thermocouple is approximately -10 mmv/°C. The phase change of Bi I → Bi II takes place at 25.4 kb at 20°C, and the change from Bi II → Bi III takes place at 27 kb at 20°C. Thus under certain circumstances appropriate thermocouples in high-pressure environments can be used to measure pressure.

2104
Kolomoets, N. V., Stil'bans, L. S. and Fateen, N. P. MEASUREMENT OF AIR HUMIDITY WITH THE AID OF SEMICONDUCTING THERMOCOUPLES. Zhurn. Tekh. Fiz. 26:686-692, Mar. 1956.

In Russian. Trans. in Soviet Phys. Tech. Phys. 1:662-668, 1956.

There is described a new construction of an automatic condensation hygrometer, in which the cooling is done by the use of a semiconducting thermoelement.

2105
Minashin, V. E. Subbotin, V. I. et al. MICROTHERMOCOUPLES USED FOR RESEARCH ON HEAT TRANSFER. Voprosy Teploobmena p. 193-199, 1959.

In Russian. Trans. no. 61-23661 available from OTS or SLA.

Information is presented on: (1) a method of welding fine thermocouples by means of an arc formed by the discharge of a bank of condensers between metal foil and the thermoelectrodes; (2) the technology for manufacturing microthermcouples and cementing them to heat exchange surfaces; and (3) the technology for applying heat resistant alundum insulation to thermoelectrode wire. (Tech. Trans. 6:305, 1961)

2106
Nippon Electric, Ltd., Tokyo, Japan. INFORMATION CONCERNING NEWLY DEVELOPED THERMOCOUPLES. 12p., graphs, 1961.

The Nippon Electric Co. Ltd. of Tokyo has recently announced the development of a new thermocouple, utilizing semi-conductor materials and a fabrication technique permitting high temperature operation. The device reportedly has many uses, including the use in power reactors and in solar batteries for space use. The report contains a general description of the device, a description of the present state of development, and basic technical information on the thermocouple.

2107
Sorokin, P. J. IMMERSION THERMOCOUPLE FOR PROLONGED MEASUREMENT OF TEMPERATURE OF MOLTEN STEEL. Aut. sv SSSR. Patent 115, 690, Nov. 29, 1958. (25895 P)

Description of a thermocouple with a watercooled housing divided into two intercommunication recesses at the working end by two diametrically opposed longitudinal partitions. The housing inside is filled with a neutral gas. (USSR Abs. Metall. Part B, no. 12:60, 1959)

2108
Suzuki, M. and Mizuguchi, K. THERMOCOUPLES USEFUL AT VERY LOW TEMPERATURES. Electrotech. Lab. Bull. (Japan) 23:488-490, Jly. 1959.

In Japanese. Performance characteristics of thermocouples composed of (1) Au + 2.1 atomic % Co versus Cu; (2) Au + 2.1 atomic % Co versus chromel; and (3) constantan versus Cu, were measured from 2 to 60°K using a constant-volume helium-gas thermometer as a standard. A graph of thermoelectric force versus temperature is given which shows that thermocouple 3 has the highest output (~40μV/°K) over the temperature range considered. (Sci. Abs. 64B: 3837, 1961)

2109
Thelke, N. R. and Shepard, R. L. HIGH-TEMPERATURE THERMOCOUPLES BASED ON CARBON AND ITS MODIFICATIONS. In High Temperature Thermometry Seminar October 1-2, 1959, Oak Ridge, National Laboratory, p. 44-52, Oak Ridge, Tenn., Oak Ridge National Laboratory, Agu. 1960.

Efforts of various workers are cited to utilize the small difference between the thermoelectric powers of graphite and carbon to form high-temperature thermocouples. Work of the authors is also described in developing flexible boron/graphite thermocouples. Results of field tests are indicated.

2110
U. S. Atomic Energy Commission, Hanford Works, Richland, Wash.

STABILITY OF CHROMEL-ALUMEL THERMOCOUPLES OF CARBON DIOXIDE AT 1000°C. 3 p., Nov. 29, 1955. (Rept. 40296)

An out-of-pile laboratory study was initiated to obtain information on the stability of commonly used thermocouples. This report summarizes the data obtained on chromel-alumel thermocouples from this study.

Tests of twenty identically prepared 26 gauge chromel-alumel thermocouples have been completed. It appears that wires of this material without protection are unsatisfactory mechanically and thermoelectrically for service in atmospheres of CO_2 at 1000°C.

2111
Ya, L., Krol, F.E., et al. THERMOCOUPLES FROM INTERMETALLIC COMPOUNDS ZnSb AND CdSb. Priborostroenie 8:28-29, 1960.

In Russian. English abstract in Chem. Abs. 55:11092, June 12, 1961.

Means were established for measuring the physical properties of the branches of the thermocouples and their respective thermo emf.

2112
Young, R. THERMOELECTRIC THERMOMETRY. Cert. Engr. 33:407-416, Oct. 1960.

Description of principles of thermocouples, materials used in their construction, methods for their calibration, and instruments employed for measuring emf produced, graduated to record temperatures. (Eng. Index p. 1498, 1960)

4. Miscellaneous

2113
Hand, I. F. THE VARIABILITY OF THE THERMOELECTRIC PYRHELIOMETER FACTOR. Mon. Weather Rev. 68:339-344, Dec. 1940.

Comparisons are made between substandard pyrheliometers and the vacuum thermocouple pyrheliometer, giving sources of error and advantages of the various types.

2114
Labartkava, E. K. A THERMOELECTRIC ULTRASONIC PICKUP WITH SEMICONDUCTING THERMISTOR. Akust. Zhurn. 6:468-471, Oct/Dec. 1960.

In Russian. Trans. in Soviet Phys. Acous. 6:468-471, Apr/June 1961.

A point semiconducting sound pickup made up of an MT-54 microthermoresistor (Karmanov design) with plexiglas thermosensitizer is considered.

2115
Laboureur, THERMOELECTRIC SOUNDER. Hydrographic Rev. 6: 175-178, illus., Nov. 1929.

A temperature measuring device for use in the deep ocean is described. In addition to purely scientific uses, it can be used by a trawler to explore fishing grounds in advance and to ascertain at once whether the sea temperature be favorable to the presence of fish above the bottom.

2116
Likhachev, N. A. A THERMOELECTRIC VESTIBULOMETER. Byull. Izobreteniu no. 14, p. 34, 1960.

In Russian. This thermoelectric vestibulometer is for examining the vestibular function of man by the calorific method and consists of a thermal irritator, introduced into the auditory meatus and having the same shape as the latter. It has the following special feature: to widen the range of application of the calorific method and obtain a quantitative estimate of the conditions of the thermal action, the thermal irritator has semiconductor thermocouples and a microthermistor, enabling the thermal irritator to be heated or cooled to the outside temperature after it has been introduced into the auditory meatus.

2117
Rex, Dietrich. THERMOELECTRIC PUMPS FOR MOLTEN METALS. Ver. Deut. Ing. Z. 103:17-19, Jan. 1961.

In German. Thermoelectric pumps for molten metals are suitable for maintaining the operation of sodium-cooled reactors in the event of failure of the main pump, or, in general, for pumping molten metals. The theoretical principles of such pumps are simple and they permit the essential operational data to be quickly estimated. A large sodium plant is above the flow pattern of the circulating metal, and the structure of the channel walls on the operation of thermoelectric pumps. (Nuclear Sci. Abs. 15:8935, 1961)

2118
SELF-CONTAINED, THERMOELECTRIC-TYPE AIR-CONDITIONED SUIT. Engrs. Dig. 22:6,8, May 1961.

Cooling of the suit, basically intended for testing the practicability of air-conditioned attire for military personnel, is effected by passing current through thermoelectric couples made of semiconductor-type materials, reversal of the current producing heat, instead of cooling.

2119
SELF-POWERED GAS FURNACES LEAD THE WAY AS THERMOELECTRIC DEVICES TAKE ON NEW JOBS. Steel 148:118, Feb. 27, 1961.

Refers to three thermoelectric devices - a home heating furnace that powers its own blower, a nuclear-powered thermoelectric generator, and a temperature controller.

2120
Texaco Experiment Inc., Richmond, Va. THE USE OF THERMOELECTRIC MATERIALS IN ELECTRICAL INITIATORS. March 1 - May 31, 1961. 21p., June 1, 1961. (Rept. EXP-342) (Tech. Memo. 1264) (Contract N178-7736) (AD-259 796)

A limited explorator effort is reported to investigate experimentaly the feasibility of developing a radio-frequency-proof squib which uses the Peltier thermoelectric effect to produce the major contribution of ignition energy. A mathematical analysis has been made of a configuration similar to those used in the experimental tests.

2121
THERMOELECTRIC METHOD FOR MEASURING SMALL FLOW-RATES. Control 4:114-115, May 1961.

A thermal device has been developed by Société pour la Diffusion d'Appareils de Mesure et de Controle for direct measurement of gas flow up to about 16 l/h and for very small liquid flows.

2122
THERMOELECTRIC MICRODETERMINATION OF MOLECULAR WEIGHTS. W. Simon and C. Tomlinson. Chimia 14:301-308, 1960.

A review, in German, with 60 references.

2123
THERMOELECTRIC SYSTEM RECORDS MACHINE PRODUCTIVE TIME. [DEVELOPMENTS TO WATCH] Prod. Eng. 32:14, Aug. 14, 1961.

A method for recording productive time that takes advantage of the thermoelectric emf set up between tool and workpiece as heat is generated at the cutting point has been developed by L. M. Ericsson, Ergo Division, Stockholm, SV, Sweden.

Although the thermoelectric emf is only a few millivolts, and can not be used to provide quantitative information on feeds and speeds, it does provide positive proof that work is taking place, and so can be used for supervision of machine processes.

2124
Webb, E. L. R. and Pulfer, J. K. LOW-IMPEDANCE THERMOELECTRIC, DEVICE POWERS TUNNEL

DIODES. Can. Electron. Eng. 5:40-43, Feb. 1961.

The power supply described consists of several Bi_2Te_3 couples in series, heated by a.c. - or d.c. - driven resistance elements and having an output impedance of 0.02 Ω. Results obtained with tunnel-diode microwave oscillators are briefly discussed.

III. THERMIONIC EMISSION
A. General Information

2125
Blount, E. I. THERMIONIC CONVERSION. In Heikes, R. R. and Ure, R. W., Jr. eds. Thermoelectricity: Science and Engineering, p. 443-457, New York, Interscience Publishers, 1961.

The physical basis of thermionic conversion is discussed and the power and efficiency which can be obtained.

2126
Cayless, M. A. THERMIONIC GENERATION OF ELECTRICITY. Brit. J. Appl. Phys. 12:433-442, figs., Sept. 1961.

A thermionic generator of electricity is essentially a diode valve in which electrons emitted from a hot cathode flow to a cooler anode, producing an electric current. From being scientific curiosities, such devices have become the subject of intense research activity in the last three years, and it is now clear that they have considerable possibilities as useful generators in a number of fields.

This article reviews this recent work and makes an assessment of the present position and future trends. Although engineering design and applications are considered, the emphasis is on the physical processes associated with these devices, and the progress which has been made into understanding them.

2127
CESIUM CELL FOR POWER CONVERSION. Electron. 33:78, 80, Jan. 29, 1960.

Popular article based on announcement of the successful conversion of heat directly into alternating current electricity in significant amounts, without use of rotating machinery or dc-ac converter.

2128
CESIUM PICKED FOR STARDOM IN SPACE. Steel 149: 139-140, Sept. 18, 1961.

Characteristics, possibilities and current uses are mentioned. Cesium is now playing a key role in the development of two Space Age power generation systems: magnetohyrodynamics and thermionic converters.

2129
Connelly, J. J., Jr. THERMIONIC ENERGY CONVERTERS. Nav. Res. (Rev.) p. 3-10, Mar. 1961.

Discussion of the theory of thermionic converters and of experimental close-spaced diode and plasma-diode models of such converters. The Navy research program for the development of a nuclear-reactor thermionic-converter system is described.

2130
General Atomic, San Diego, Calif. RESEARCH ON CESIUM-VAPOR CELLS EMPLOYING CARBIDE CATHODES. Yearly Technical Summary Report, by R. W. Pidd and H. L. Garvin. 43 p., Feb. 7, 1961. (Rept. 1973) (Contract Nonr-3193(00)).

Vacuum emission studies were made on cathode materials containing ZrC and UC of various proportions. A cathode of $ZrC_{0.80}$-$UC_{0.20}$ solid solution was installed in a cesium thermionic diode and studies were made of the electrical output characteristics, ion generation mechanism, and effective electron temperatures at various cesium pressures.

2131
GENERATING POWER FROM THE SUN. Electron. 34:76, 78-79, Sept. 15, 1961.

New types of thermionic converters under development are described.

2132
GETTING ELECTRICITY FROM HEAT, DIRECT THERMIONIC CONVERTERS. Power Eng. 62:87, Jan. 1958.

This news item describes the thermionic converter developed by General Electric.

2133
HEAT TO ELECTRICITY, A NEW APPROACH: THERMIONIC CONVERTER. Power 102:86-87, Jan. 1958.
Electrons given off from a 2500°F cathode are collected for direct use as an electric current. Developed by GE, the experimental unit boasts 8% efficiency, promises 30%.

2134
HEAT TO ELECTRICITY: GE'S THERMIONIC CONVERTER. Chem. & Eng. News 35:22, Dec. 2, 1957.

GE's thermionic converter changes heat directly to electricity; 30% efficiency the ultimate hope.

2135
Johnson, F. M. DIRECT CONVERSION OF HEAT TO ELECTROMAGNETIC ENERGY. RCA Rev. 22:21-28, figs., Mar. 1961.

The conversion of heat into electromagnetic energy is achieved by utilizing the intrinsicially unstable space-charge properties of a thermionic cesium plasma diode. Experimental studies of this phenomenon are described. A physical model for the observed relaxation oscillations is proposed which is in qualitative agreement with experiments.

2136
NAVY EYES ELECTRON MOTORS; THERMOELECTRIC SHIP PROPULSION SYSTEM. Electron. 31:26, May 2, 1958.

This news item states that the basic unit of the thermoelectric engine would be a thermionic converter. In submarines, where such converters would be noiseless a major breakthrough would be militarily important. There are no real details on the converter.

2137
Teutsch, W. B. CONVERSION OF HEAT TO ELECTRICITY IN CESIUM CELLS. In Conference on Physical Electronics, 20th. Report, p. 70-71, Cambridge, Mass., Massachusetts Institute of Technology, 1960.

A brief review is given of experiments carried out to study the conversion of heat to electricity in diode configurations, with varying amounts of cesium vapor. The statement is made that the simple thermionic model has a somewhat greater range of application and validity than may be anticipated from the arguments given so far. Positive identification of a mechanism of alternating-current production is needed.

2138
U. S. Air Force. Wright Air Development Division, Wright-Patterson Air Force Base, Ohio. SECOND STATUS REPORT ON THERMIONICS, by N. N. Noe and O. P. Breaux. 37 p., Jan. 1961. (Tech. Note 59-335, Pt. II)

A complete list of Governmental contracts covering work on thermionic energy conversion as well as summary of work done under these contracts.

B. Theory

2139
Grodko, V. A. et al. EFFECT OF WORK FUNCTION DIFFERENCES OF ELECTRODES ON THE OUTPUT PARAMETERS OF A THERMIONIC CONVERTER. Radiotekh. i Elekr. 5:2046-2051, Dec. 1960.

In Russian. Partial trans. in Electron. Express 3:28-32, figs., Mar. 1961.

The paper analyzes the dependence of the power and efficiency of a transducer with complete neutralization of the space charge on the difference between the electrode work functions. It is proven that for fixed values of the electrode temperatures and the anode work function the optimum output parameters with respect to the entire volt-ampere characteristic correspond to a transducer with a cathode work function equal to the anode work function. Thus it is demonstrated that the idea according to which it is in principle necessary to maintain a substantial difference between the electrode work functions of the transducer does not correspond to the essence of the phenomenon.

2140
Grodko, V. A., Solotarevskii, V. S., et al. ON THE INFLUENCE OF WORK-FUNCTION DIFFERENCE OF THE ELECTRODES OF A THERMOELECTRON CONVERTER UPON ITS OUTPUT PARAMETERS. Radiotekh. i Elektr. 5:2046-2051, 1960.

In Russian. Trans. in Radio Eng. & Electron. (USSR) 5(no. 12):258-267, 1960.

The dependence of power and efficiency of a converter with full neutralization of the space charge upon the difference of the work functions of the electrodes is investigated. It is shown that for given temperatures of the electrodes and work function of the anode the best output parameters over the whole current-voltage characteristic are those of a converter with a work functio.. of the cathode equal to the work function of the anode. It is thus shown that the opinion held, according to which a substantial difference in the work functions of the electrodes of a converter is necessary in principle, does not correspond to the reality of the phenomenon.

2141
Ionov, N. I. ON THE THEORY OF VACUUM THERMIONIC DIODES. Zhurn. Tekh. Fix. 30:1210-1214, Oct. 1960.

In Russian. Trans. in Soviet Phys. Tech. Phys. 5:1147-1151, Apr. 1961.

Derives, in an easily applicable form, the dependence of the characteristics of fully space-charge compensated diodes on the work functions and temperatures of the plane electrodes. A qualitative discussion is given of the application of the results to a real case of the electrodes made up of regions with different work functions.

2142
Morgulis, N. D. ON THE ROLE OF CONTACT-POTENTIAL DIFFERENCE IN THE THERMOELECTRONIC CONVERSION OF ENERGY. Radiotekh. i Elekr. 5:2052-2053, 1960.

In Russian, Trans. in Radio Eng & Electron. (USSR) 5(no. 12):268-269, 1960.

Comments on the article by V. Grodko, V. Zolotarevskii, et al (On the Influence of Work-Function Difference of the Electrodes of a Thermoelectron Converter upon its Output Parameters), Radiotekh. i Elektr. 5:2046-2051, 1960.

2143
"Quantum". THERMIONIC CONVERSION. [THE FRINGE OF THE FIELD]. Electron. Tech. 38:245-247, illus., Jly. 1961.

This is merely a short and simple discussion of the principles involved, and an attempt to discover why it works at all.

2144
Rashevsky, N. THE THEORY OF THERMIONICS. Phys. Rev. 27:810, June 1926.

Abstract of paper presented at the April meeting of the American Physical Society.

"An expression for the free energy of a metal is derived, special account being taken of the fact that thermionic phenomena are essentially surface phenomena. The expression for the free energy thus obtained is substituted in the general formulae for thermionic emission previously derived. The final formula thus obtained gives indications for the understanding of the fact that while for pure metals the "A" constant of Richardson's equation has almost the universal value postulated by Dushman, it has a largely different value for oxides and absorbed films. The question as to the existence of an electric double-layer on the surface of a metal is discussed, as well as the influence of such a layer on thermionic emission. It is shown that while the existence of such a layer follows from Schottky's Equilibrium Theorems, the same theorems lead to the conclusion that the temperature change of the moment of such a layer is relatively small. Its value may be approximately estimated." Entire item quoted.

1. Emission Phenomena

2145

Abrams, R. H., Jr. and Jamerson, F. E. THERMIONIC EMISSION OF UC-Nb. J. Appl. Phys. 32:1783-1784, figs., Sept. 1961.

The thermionic constants and spectral emissivity have been measured on a uranium carbide-niobium disk, UC (80 volume %)-Nb (20 volume %), of 2.34 cm in diameter and 0.51 cm in thickness, and results are given.

2146

Dykman, I. M. and Tomchuk, P. M. INFLUENCE OF AN ELECTRIC FIELD ON ELECTRON TEMPERATURE, ELECTRICAL CONDUCTIVITY AND THERMIONIC EMISSION IN SEMICONDUCTORS. III. THERMIONIC EMISSION. Fiz. Tverdogo Tela 3:632-641, Feb. 1961.

In Russian. Trans. in Soviet Phys. Solid State 3:464-470, figs., Aug. 1961. Also available as Trans. MCL-1092 of Aerospace Tech. Info. Center. (AD261814) OTS price $1.60.

The spherically symmetrical part of the fast conduction electron distribution function in a semiconductor in the presence of an electric field has been determined. Criteria for the field which causes perceptible electron gas heating and calculated the thermionic current has been determined. Criteria for the field which causes perceptibl electron gas heating has been establish l and thermionic current calculated.

2147

Franklin Institute. Bartol Research Foundation, Swarthmore, Pa. ELECTRICAL CONDUCTION AND THERMIONIC EMISSION IN SEMICONDUCTORS, by O. A. Weinreich, W. E. Danforth, and D. L. Goldwater. 2 issues, Sept. 30, 1952, Jan. 31, 1953. (Contract Nonr-62800)(AD-291, AD-9109)

Investigation was made of the electrical conductivity of crystalline ThO_2 in different gases at atmospheric pressure.

2148

Fry, T. C. THERMIONIC CURRENT BETWEEN PARALLEL PLANE ELECTRODES: VELOCITIES OF EMISSION DISTRIBUTION ACCORDING TO MAXWELL'S LAW. Phys. Rev. 17:441, Apr. 1921.

The electrical equations applying to this problem are developed without neglecting the distribution of initial velocities, which in the first place is allowed to be entirely general. Maxwell's distribution of velocities is then considered in detail and a complete solution obtained. Curves from which to compute the space current when Maxwell's distribution applies are presented, together with an illustrative example of their use. Curves are also included showing the deviation of the current-voltage relation from the 3/2-power law; the variation of the minimum potential between the electrodes with plate voltage, and also the variation with plate voltage of the distance between the cathode and the point at which this minimum potential occurs.

2149

General Electric Co. Research Laboratory, Schenectady, N. Y. INVESTIGATION OF EMISSION FROM ELECTRODE SYSTEMS IN CESIUM VAPOR, by M. D. Gibbons.

19p., figs., Mar. 1961. (AFCRL-400) (Sci. Rept. 9) (Contract AF-19(604)5472) (AD-260 365)

This report describes emission measurements from various electrode systems, and some observations on hot cathode discharges in cesium vapor. Emission measurements give the boundary conditions at the electrode surfaces in the thermionic converter, and possibly give an indication of the relative bond strength of cesium to the electrode surface. The study has shown the importance of the interplay of electron space charge problems and surface ionization. The general form of the tantalum-cesium emission system has been measured. Tantalum offers a more suitable anode material for the converter than tungsten. The so-called second mode has been shown to be a hot cathode discharge.

2150
General Electric Co. Research Laboratory, Schenectady, N. Y. POTENTIAL DISTRIBUTIONS IN A LOW PRESSURE THERMIONIC CONVERTER, by P. L. Auer. 24 p., Jly. 1960. (AFCRL-282) (Sci. Rept. 4) (Contract AF19(604)-5472)

A planar diode model of a low pressure cesium-filled thermionic converter is treated. It is assumed that all ions and electrons are created at the surface of the hot cathode with a Maxwellian distribution corresponding to the cathode temperature. The charge species are then assumed to move through the plasma consisting of electrons, ions, and neutral cesium atoms as free particles under the influence of their mutual space charge field. A method is outlined by which the potential distributions corresponding to different operating conditions may be calculated completely. In this fashion the operating characteristics of the converter may be related to the self-consistent space charge potentials. Instabilities as possible sources of tube oscillations are briefly discussed.

2151
General Electric Co. Research Laboratory, Schenectady, N. Y. RESEARCH ON THERMIONIC CONVERTERS. 145 p., June 1961. (AFCRL-430) (Contract AF19(604)-5472)

Research on thermionic converter characteristics and associated phenomenon of vacuum, vapor, and crossed-field converters is reported as well as the development of a new ceramic for use in vacuum and vapor converters.

2152
Greenberg, J. EFFECT OF A MAGNETIC FIELD ON THERMIONIC EMISSION FROM MOLYBDENUM. Phys. Rev. Ltrs. 1:476, Dec. 15, 1958.

An experiment that was performed to explore the possible effect of an external magnetic field on thermionic emission from a clear metal surface demonstrated that an applied field of 6000 gauss or less has no effect on the saturation current density. The purpose of this study was to resolve, if possible, the disagreement between the work of Shelton and that of Nottingham and Hutson on the energy distribution of thermionically emitted electrons.

2153
Harrison, T. A STUDY OF THE CONCURRENT VARIATIONS IN THE THERMIONIC AND PHOTOELECTRIC EMISSION FROM PLATINUM AND TUNGSTEN WITH THE STATE OF THE SURFACES OF THESE METALS. Phys. Soc. Proc. 38: 214-233, Apr. 15, 1926.

Attempt is made to measure the thermionic and photoelectric work functions for the same specimens of tungsten and platinum. It is found that in all cases the results depend greatly on the previous heat treatment of the material. In the case of platinum the curves showing the dependence of photoelectric sensibility on the wavelength of the irradiation are of four different types, while as regards thermionic properties the specimens can take up either a "large emission" or a small emission" state, according to their treatment. The photoelectric work

function of platinum came out greater than the thermionic, but no definite results were obtained for tungsten.

2154
Morgulis, N. D., and Naumovets, A. G. THE USE OF THERMIONIC EMISSION FOR THE DIRECT CONVERSION OF HEAT ENERGY TO ELECTRICAL ENERGY. Fiz. Tverdogo Tela 2:536-542, Mar. 1960.

In Russian. Trans. in Electron. Express 2:14-17, figs., June 1960.

As a development of a previous paper, this paper studies the problem of the direct conversion of heat energy to electrical energy by the use of thermionic emission from an active metal-film -cathode in cesium vapors. Here we use the partial compensation of the electron charge by Cs ions which occur as the result of thermal ionization on sectors of the metal surface of the cathode which have been stripped of the film. Thus it is possible to obtain an appreciable short-circuit electron current and an appreciable energy efficiency for such a conversion. Such studies of thermal ionization can also be used independently for studying the nature of absorption nonuniformities in various film cathodes.

2155
Nottingham, W. B. THE THERMIONIC CONVERSION OF HEAT TO ELECTRICITY. In National Conference on Electron Tube Techniques, ed. by David Slater, p. 72-76, New York, Pergamon Press, 1961.

Importance of emitter and transport properties of the electrode space are emphasized in the determination of the current that can flow across the thermionic diode used as the converter of heat to electric power.

2156
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. RESEARCH IN ELECTRON EMISSION FROM SEMICONDUCTORS. 3 issues, Mar., June, Sept. 1960. (Repts. 6, 7, and 8 (Final)) (Contract DA36-039-sc-78155)

Concerns research leading to a better theoretical understanding of thermionic and hot electron emission and to new materials with useful electron emission characteristics.

2157
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. RESEARCH IN ELECTRON EMISSION FROM SEMICONDUCTORS. 2 issues, Dec. 1960, Mar. 1961. (Repts. 9, 10) (Quart. Repts. 1, 2) (Contract DA36-039-sc-87388) Continuation of Contract DA36-sc-78155)

2158
Reimann, A. L. THERMIONIC EMISSION. 324 p., fig., New York, Wiley, 1934.

General survey and history, electron emission from clean metals, from contaminated metals: oxide cathodes, modern general theory of electron emission, and emission of ions.

2159
Republic Aviation Corp. Plasma Propulsion Laboratory, Farmingdale, N. Y. EFFECT OF MAGNETIC FIELDS ON THERMIONIC POWER GENERATION, by Alfred Schock. 70p., Jan. 1960. (Tech. Rept. 60-1)

It is demonstrated that the high currents present in large thermionic power generators produce magnetic fields which have a strong adverse effect on electron transmission and energy conversion efficiency. A method for overcoming the adverse effect of the self-induced field is presented and analyzed. It is shown that the superposition of a magnetic field normal to the emitting surface will permit efficient operation of large power generators. (Nuclear Sci. Abs. 15:15127, 1961)

2160
Republic Aviation Corp. Plasma Propulsion Laboratory, Farmingdale, N. Y. OPTIMIZATION OF EMISSION LIMITED THERMIONIC GENERATORS, by Alfred Schock. 13 p., figs., Feb. 1961. (Tech. Rept. 61-3A) (Contract Nonr-3285(00)) (AD-255 550)

Equations are derived describing the performance of space charge neutralized thermionic converters with negligible transport effects. For a given anode work function and cathode temperature, optimization of the other system parameters leads to an expression for the maximum attainable conversion efficiency, in terms of the fundamental physical constants c, m, c and k. The calculated results, presented graphically, suggest several distinct modes of high efficiency operation, and lead to a number of interesting conclusions about converters with cesium coated cathodes.

2161
Rumyantsev, A. P. and Tavastsherina, O. G. THE PROBLEM OF DETERMINING THE TEMPERATURE OF THERMIONIC EMITTERS. Inzh. Fiz. Zhurn. 3:48-55, 1960.

In Russian. In the determination of the thermionic work function of electrons a major role is played by the error contained in the determination of metal surface temperature. The most expedient method of determining the cathode temperature is to determine the base resistance as a function of temperature. The influence of certain factors on the accuracy of such measurements is studied here. The first part of the paper deals with errors imputable to imperfect circuit elements. In this connection the authors discuss the short-circuiting of the cathode by the balancing of the bridge, the heating of the circuit elements by the work current, and the production of an artificial zero point. The cooling effect of the cathode support is thoroughly discussed in the second part. The third part of the paper deals with the change in the contact resistance between cathode and support, and the fourth part is devoted to the temperature drop in the cathode coating. It is shown in the discussion of results that the largest error contribution is made by the cooling effect of the cathode support, while the second largest comes from the temperature drop in the cathode coating. The error produced by the artificial zero point is small, and, because it is almost compensated by other errors, it can be neglected.

2162
Shibata, Chokichiro. ELECTRON EMISSION FROM OXIDE-COATED CATHODE SUBJECT TO STRONG ELECTRIC FIELD. Phys. Soc. Japan. J. 16:51-61, 1961.

The electron emission from the oxide coated cathode was measured in a wide range of electric field intensity, where a deviation from Shottky effect appears.

The phenomena could be explained by considering the emission increase by avalanche effect in the oxide layer. The calculation of the enhanced emission current was performed and compared with the measured results.

2163
Steel, H. L. THEORY OF THE CESIUM PLASMA ENERGY CONVERTER WITH A TUNGSTEN CATHODE. In Snyder, N. W., ed. Energy Conversion for Space Power. p. 177-199, New York, Academic Press, 1961. (Process in Astronautics and Rocketry vl. 3)

The behavior of a diode converter with a tungsten cathode and containing cesium is described by considering three different ranges of cesium pressure. A method of measuring the rate of ionization at a hot cathode surface and a method of determining electron temperature in the two lower regions are presented.

2164
Tomchuk, P. M. INFLUENCE OF ELECTRIC FIELD ON ELECTRON

TEMPERATURE, ELECTRICAL CONDUCTIVITY AND THERMIONIC EMISSION OF SEMICONDUCTORS. Fiz. Tverdogo Tela 3:1019-1030, Apr. 1961.

In Russian. Trans. in Soviet Phys. Solid State 3:740-748, figs., Oct. 1961.

The distribution function for the electron gas in the presence of constant electric field was found from a kinetic equation. An account was taken of the electron interactions with themselves (including both long- and close-range collision) and with the plasma oscillations. The relation between the momenta in the Chapman-Cowling method and those obtained from Landau equation was established. An estimate was made of the influence of plasma oscillations on the electrical conductivity. The applicability limits of Landau method are discussed.

2165
Tomkova, E. DIRECT TRANSFORMATION OF THERMAL ENERGY INTO ELECTRIC ENERGY BY MEANS OF THERMAL EMISSION. Czechoslov. J. Phys. no. 5:430, 1960.

In Czechoslovakian.

Several diode systems employing either directly heated tungsten cathodes (the collector being in the form of molybdenum cylinders of various diameters) or a flat or cylindrical impregnated cathode were measured. The negative space charge of electrons was compensated by positive cesium ions produced by the thermal emission at the cathode. The effect of the presence of a metallic polonium deposited on a molybdenum base on the efficiency of the diodes was investigated. (Nuclear Sci. Abs. 15:16208, 1961)

2. Related Phenomena

2166
D'Angelo, N. LOW-FREQUENCY OSCILLATIONS IN CESIUM THERMIONIC CONVERTERS. Phys. Fluids 4:1054-1055, Aug. 1961.

Letter to the editor concerning the presence of positive ion sheath close to the cathode.

C. Electrode Properties

2167
Bartol Research Foundation, Swarthmore, Pa. RESEARCH INVESTIGATION OF CATHODE EMISSIVE MATERIALS. Final Report, by W. E. Danforth. 74 p., Apr. 15, 1961. (AFCRL-366) (Contract AF19(604)3904)

Thermionic and desorption properties of a thorium monolayer on tungsten.

2168
Battelle Memorial Institute, Columbus, Ohio. INVESTIGATIONS OF RARE-EARTH OXIDE CATHODES, by J. B. Baker and G. B. Gaines. 8p., illus., Feb. 1, 1961. (AFCRL-90) (Sci. Rept. 6) (Contract AF19(604)-5691) (AD-253 505)

It was found that the inclusion of a small amount of nitrocellulose in a coating composed of 75% Nd_2O_3 and 25% Gd_2O_3 had no appreciable effect upon the emission, except, perhaps, to cause activation to occur at a lower temperature. A cathode containing 90% Gd_2O_3 and 10% Nd_2O_3 gave an emission level less than 0.1 amp-sq cm at 1400°C. Initial indications show that the high emission from Gd_2O_3 can be reproduced. The reason for the high activation is not yet known and needs further investigation.

2169
Battelle Memorial Institute, Columbus, Ohio. INVESTIGATIONS OF RARE-EARTH OXIDE CATHODES. Final Report, by J. B. Baker and G. B. Gaines. 24 p., illus., Mar. 31, 1961. (AFCRL-183) (Contract AF19(604)5691) (AD-255 304)

High thermionic-emission levels were obtained from gadolinium oxide

and from a mixture of 75 Nd_2O_3 - 25 Gd_2O_3 but special activating procedures were required to accomplish this. The emission properties of the oxide mixtures differed for various refractory-metal bases with the highest emission currents being obtained with tantalum bases. The presence of carbon in the coating of a cathode composed of the 75 Nd_2O_3-25 Gd_2O_3 mixture resulted in higher activation than was obtained without the carbon. Gadolinium oxide gives higher emission than thorium oxide in the temperature range of 1200 to 1500°C.

2170
Bol'shov, V. G., Dobretsov, L. N., Zharinov, A. A. et al. EMISSION PROPERTIES OF GERMANIUM TREATED IN CESIUM VAPOR. Fiz. Tverdogo Tela 1:1768-1770, Nov. 1959.

In Russian. A brief report is given of an experimental investigation of thermionic, photoelectric and secondary electron emission of n-type Ge single crystals and of Ge films deposited on glass or on Ta foil after Cs-vapor treatment. (IRE Proc. 49:409, Jan. 1961)

2171
Bondarenko, B. V., Ostapchenko, E. P. and Tsarev, B. M. THERMIONIC PROPERTIES OF ALKALI EARTH METAL TUNGSTATES. Radiotekh. i Elektr. 5:1246-1253, Aug. 1960.

In Russian. Trans. in Radio Eng. & Electron. USSR 5(no. 8):77-88, figs, 1960.

Paper presented at the 9th All-Union Cathode Electronics Conference, Oct. 21-28, 1959, Moscow.

The results of measurements of the thermionic properties of systems of alkali-earth metal tungstates of various compositions, obtained by sintering in air (or in hydrogen) are presented. The work functions of cathodes based on these compounds were determined by the theoretical equation of emission from solid bodies. The cathode samples were examined by X-ray and electron microscope techniques both before and after determination of their thermionic properties.

2172
Bowman, M. G. CHEMISTRY OF FUEL ELEMENT CATHODE MATERIALS. In Snyder, N. W., ed. Energy Conversion for Space Power. p. 201-209, New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3)

Some fundamental properties of UC, ZrC and ZrC-UC are described and related to the practical problems of: (1) the useful lifetime of cathodes with respect to vaporization losses; (2) the compatability of cathode materials with supporting conductors; and (3) methods of bonding fuel element materials to support materials.

2173
Coltman, John. DEVELOPMENT OF MATERIALS FOR THERMIONIC GENERATORS. Nuclear En. p. 530-532, Nov. 1960.

The thermionic generator is a concept which promises to open up new areas in power generation at high-operating temperatures. Although still in early stages of development, thermionic generators offer promise in applications where compactness, lightness in weight, simplicity, and high efficiency are required. The materials used in these generators must have a high heat of vaporization combined with a low work function (the potential difference between the interior and exterior of the solid material), and must be capable of operation at temperatures to ~4500°F for long periods of time. Several materials for which the efficiency has been calculated are: lanthanum boride, mixed carbides, thoriated tungsten, tantalum carbide, and tungsten. Nuclear sources lend themselves to thermionic converters because they can provide temperatures limited only by the structural properties of the materials used. It is pointed out that there has been no particular urge to find or produce materials having the peculiar properties demanded by the thermionic converter. (Nuclear Sci. Abs. 15: 7688, 1961)

2174
General Atomic, San Diego, Calif. INVESTIGATIONS OF CARBIDES AS CATHODES FOR THERMIONIC SPACE REACTORS. 39 p., Aug. 31, 1961. (Rept. 2548) (Quart. Prog. Rept. 1) (Contract NAs-5-1253)

Investigations of the physicochemical properties of UC-ZrC thermionic cathode materials at temperatures up to 2400°K.

2175
General Electric Co. Research Laboratory, Schenectady, N. Y. COMPATIBLE ALKALINE EARTH OXIDE SYSTEM FOR VACUUM THERMIONIC CONVERTERS, by M. D. Gibbons. 15p., Mar. 1961. (AFCRL-299) (Sci. Rept. 8) (Contract AF19(604)5472) (AD-260 364)

Advantages and disadvantages are presented of alkaline earth oxide systems for use as anode and cathode coatings in the vacuum converter. The coating properties used to determine the choice of the various systems are: (1) low anode work function; (2) a stable cathode capable of delivering a large emission current; (3) the anode and cathode coatings must be compatible with each other during life. These properties have led to a choice of a system consisting of a strontium calcium oxide for the cathode and a barium strontium oxide for the anode. Emission measurements and evaporation rates for strontium calcium oxide on different base metals are presented.

2176
General Electric Co. Research Laboratory, Schenectady, N. Y. THERMIONIC EMISSION FROM A TANTULUM CRYSTAL IN CESIUM OR RUBIDIUM VAPOR, by H. F. Webster. 10 p., Mar. 1961. (Sci. Rept. 6) (AFCRL-284) (Contract AF19(604)5472) (AD-260-362)

Thermionic emission has been measured from a tantalum crystal which has had its work function altered by an adsorbed layer of cesium or rubdium. The emission density is strongly dependent upon the crystallographic face of the tantalum, and the 110 face yields the peak emission for both of the alkali metals used. An additional emission peak is obtained from the 100 face when rubidium is used. Details of the measurement techniques are presented.

2177
Houston, J. M. THERMIONIC EMISSION OF REFRACTORY METALS IN CESIUM VAPORS. Am. Phys. Soc. Bull. 6:358, June 22, 1961.

Abstract only of paper presented at 1961 Summer meeting of the American Physical Society, Mexico City, June 22-24, 1961.

"The thermionic emission of six polycrystalline refractory metals was measured in Cs vapor using the "plasma anode" technique described by Marchuk.[1] In this technique a small loop of wire is immersed in a Cs plasma in a conventional gas discharge tube, and run negative with respect to plasma potential. The incoming ion current to the loop neutralizes the outgoing thermionic emission, and allows large emission densities to be measured before encountering electron space charge. To date measurements have been made only at low Cs pressures. At a Cs reservoir temperature of 100°C and with all six probes in the same plasma under identical conditions, the peak of the emission vs emitter temperature curve was found to occur at approximately the following emission current densities in amp/cm^2: W, $7x10^{-3}$ (agrees well with Taylor-Langmuir[2]); Re, $5x10^{-3}$; Mo, $4x10^{-3}$; 50% Mo-W alloy, $2x10^{-3}$; Ta, $1x10^{-3}$; Nb, $1x10^{-4}$." Entire item quoted.

2178
Kmetko, E. A. ANOMALOUS THERMIONIC EMISSION OF SOME BORIDES AND CARBIDES OF RARE EARTH AND TRANSITION ELEMENTS. Phys. Rev. 116:895-896, Nov. 15, 1959.

Thermionic emission constants, A*, up to several thousand times larger than the A_0 (120 amp/$cm^2-°K^2$)

predicted theoretically for metals have been reported for several compounds involving transition metals and rare earths with boron and carbon. It is suggested that such anomalously large emission constants, as well as some anomalously small ones, are due to the relatively large distances between metal atoms as a result of which the energy bands originating from the incomplete atomic f and/or d sublevels are narrow enough for nondegeneracy to occur in the experimental temperature range.

2179
Stanford University. Electronics Laboratories, Menlo Park, Calif. PHOTOELECTRIC EMISSION AND THE WORK FUNCTION OF SILICON, by C. C. Wang. 72p., illus., Nov. 21, 1960. (Tech. Rept. 1654-1) (Contract DA 36-039-sc-85339) (AD-249 867)

The photoelectric emission was observed from degenerate n-type silicon samples and p-type samples. An analysis of the spectral response yields information about the photoelectric response of the conduction electrons, the position of the surface states, and the band structure of the samples under investigation. The work reported here went further by applying the techniques of photoelectric emission to determine the silicon samples of different doping. Even though the simple band model of solids is at best a poor approximation for degenerate samples of semiconductors, a study based on the simple band model of the effect of impurity content on the electron affinity is not altogether meaningless. It was found that the difference in electron affinity, as determined by spectral analysis, between an n-type sample with 2 x 10 to the 20th power carriers/cc and a p-type sample with 10 to the 17th power carriers/cc was about 0.28 to 0.35 ev, which agreed closely with the rough theoretical estimate of 0.30 ev. (TAB p. 147, Mar. 15, 1961)

2180
U. S. Air Force, Cambridge Research Laboratories, Bedford, Mass. INVESTIGATIONS OF RARE-EARTH OXIDE CATHODES, by J. B. Baker and G. B. Gaines. 16p., Aug. 1, 1960. (AFCRL-TN-60-977) (PB 152 538)

Thermionic emission was determined for a mixture of neodymium and gadolinium oxides on refractory-metal bases of Ta and Mo, as well as for an additional sample of an undoped W wire. The emission level at 1400°C was about 0.15 to 0.35 amp/cm^2 for all cathodes. Prospects appear good for obtaining higher currents by adding reducing agents to the coating.

2181
Webster, H. F. THERMIONIC EMISSION FROM A TANTALUM CRYSTAL IN CESIUM OR RUBIDIUM VAPOR. J. Appl. Phys. 32:1802-1803, Sept. 1961.

Thermionic emission has been measured from a hemispherical tantalum crystal which has its work function altered by an adsorbed layer of alkali metal. The emission density is strongly dependent upon the crystallographic face of the tantalum and the emission pattern changes are different for cesium and rubidium.

D. Plasma Properties

2182
General Electric Co. Research Laboratory, Schenectady, N. Y. CESIUM ION NEUTRALIZATION OF THERMIONIC CONVERTERS, by J. M. Houston and M. D. Gibbons. 1/4 in. thick, Mar. 1961. (AFCRL 283) (Sci. Rept. 5) (Contract AF-19(604)5472) (AD-260 361)

A simple model of ion neutralization is assumed in which all ions are created by surface ionization at the hot cathode surface. Calculations are made of the values of cathode work function and temperature where Cs ion neutralization of a diode can exist. Experimental results in reasonable agreement with the calculations are presented.

2183
General Electric Co. Vallecitos Atomic Laboratory, Pleasanton,

Calif. PLASMA AS A THERMOCOUPLE LEG, by J. H. Ingold and Lewis Tonks. 15p., Dec. 31, 1960. (Rept. 3484)

The thermoelectric power of the plasma diode was calculated using concepts from the kinetic theory of gases. The result is independent of the electrode work functions and is in close agreement with that which was obtained for an n-type semiconductor.

2184
Hernqvist, K. G. PLASMA SYNTHESIS AND ITS APPLICATION TO THERMIONIC POWER CONVERSION. RCA Rev. 22:7-20, figs., Mar. 1961.

The work described in this paper pertains to thermionic energy converters (T. E. C.) in which the electron space charge is neutralized by positive-ion injection into the interelectrode space. A novel method of representing the potential energy diagram for the plasma is described; this method facilitates the understanding of the interaction between plasmas and solids. Based on this model, a detailed plasma energy balance for different types of cathode materials is given.

2185
Lewis, H. W. and Reitz, J. R. EFFICIENCY OF THE PLASMA THERMOCOUPLE. J. Appl. Phys. 31:723-727, Apr. 1960.

The efficiency of a thermionic converter containing cesium ions is calculated for the regime, in which the plasma density is sufficiently high so that the random current density, nev/4, is large compared to the actual current density. Under these circumstances, positive space charge barriers are set up at the electrodes, and the plasma region is many free paths in length. The output voltage V is determined for various currents by a consistent solution of the electrical and thermal conduction problems. The efficiency of the thermocouple is then deduced from the calculated current-voltage characteristic and the appropriate electron temperature distribution. Over-all efficiencies up to 32 percent are predicted for a typical thermocouple circuit.

2186
Morgulis, N. D. and Korchevoi, U. P. PROPERTIES OF CESIUM PLASMA OF A THERMOELECTRON ENERGY CONVERTER. Akad. Nauk. SSSR. Dok. 136:336-338, 1961.

In Russian. Trans. in Electron. Express 3:33-34, figs., June 30, 1961 and Soviet Phys. Dok. 6:71-73, Jly. 1961. Also NRL Trans. 846.

Devices for direct conversion of heat energy to electric energy by thermionic emission are almost always filled with cesium vapor at a corresponding pressure p to neutralize the electronic space charge of the thermionic Cs ions arising at the cathode, and to set up the proper contact-potential difference V_k between the converter electrodes. The Cs vapors, usually responsible for the appearance of an interelectrode plasma, may exert a strong effect on the physical characteristics of the converter, e.g. an effect similar to that discussed theoretically in ref. 2. In some papers, major importance is attributed to the role of the plasma in this type of "plasma diode." The present paper was compiled to provide data on the properties of a plasma of this kind.

2187
National Academy of Sciences. Na National Research Council. Materials Advisory Board, Washington, D. C. DEVELOPMENT AND POSSIBLE APPLICATIONS OF PLASMA AND RELATED HIGH-TEMPERATURE GENERATING DEVICES. 229p., Aug. 30, 1960. (Rept. MAB-167-M) (Contract DA36-039-sc-76436)

A description and the general nature of plasma are given. Methods for obtaining ultrahigh temperatures, applications of plasma and related devices, status of research completed or in progress, and the physics and chemistry of plasma flames are discussed. Questionaires were sent to more than 250 individuals and establishments to determine the level and direction of current activities in materials research and development. The replies from these questionnaires are summarized. Brief summaries of selected references are included. (Nuclear Sci. Abs. 14:24937, 1960)

2188
Nottingham, W. B. GENERAL THEORY OF THE PLASMA DIODE ENERGY CONVERTER. In Conference on Physical Electronics, 20th, Report, p. 95-114, Cambridge, Mass., Massachusetts Institute of Technology, 1960.

A new concept is put forward, namely, that the presence of a suitable pressure of cesium atoms near a hot emitting surface results in an ionization so copious that an ion space-charge sheath can be built up at the surface.

2189
Samsonov, G. V. and Neshpor, V. S. THERMIONIC EMISSION PROPERTIES OF TRANSITION METALS AND THEIR COMPOUNDS WITH B, C, N, AND Li. Akad. Nauk. Ukrain. SSR. Voprosy Poroshkovoi Met. i Prochnosti Materialov. no. 7, p. 99-104, 1959.

In Ukranian. The resistance of transition metals plotted as a function of the number of electrons in nonsaturated d-shells shows a reduced resistance of metals with increased d-shell quantum numbers and with increased numbers of electrons. The resistance (and consequently the electron scattering) is increased with increased ξ_d for groups IV to VI and varies very little for groups VII and VIII. Analogous phenomena are observed with the lanthanides with defective 4f shells. The magnitude ξ_f for this group is $\sqrt{1/2 Z_{4f^n}}$, where Z is the number of electrons in the 4f shell. The formation of transition metal compounds with boron, carbon, nitrogen, and silicon results in changes of electron states in the initial metal crystals. However, certain regularities are noticed in the electrical properties of compounds due to the peculiar atomic structure of the components. (Nuclear Sci. Abs. 14:16032, 1960)

2190
Steele, H. L. CESIUM PLASMA ENERGY CONVERTER: EVIDENCE OF A POSITIVE ION SHEATH AT THE CATHODE. In Conference on Physical Electronics, 20th, Report, p. 76-87, Cambridge, Mass., Massachusetts Institute of Technology, 1960.

It is the purpose of this paper to represent the evidence and to test the general theory of cesium converters by calculating the magnitude of the electron accelerating positive ion sheath and comparing this energy with the measured electron temperatures.

2191
Wolff, M. F. PLASMA ENGINEERING - Part III: APPLICATIONS OF PLASMA. Electronics 34:29-35, illus., Sept. 1, 1961.

The part played by plasma in thermionic power conversion and in MHD power conversion is discussed.

2192
Zollweg, R. J. and Gottlieb, Milton. OSCILLATIONS AND SATURATION CURRENT MEASUREMENTS IN THERMIONIC CONVERSION CELLS. J. Appl. Phys. 16:890-894, figs., May 1961.

Radio frequency oscillations observed in cesium-filled thermionic diodes are interpreted on the basis of a model which assumes that the cesium ions oscillate in an excess negative charge potential well outside the cathode. A simplified theoretical treatment shows that the period at the onset of oscillations is linear with cathode-anode spacing

in agreement with experiment, and relates the oscillation period to the ratio of cell current to saturation emission current. It is found that the rapid decrease of oscillation amplitude as the cell current reaches a critical value can be used to measure saturation emission currents.

E. Design Parameters

2193
Bloss, W. THEORETICAL TREATMENT OF GAS-FILLED THERMIONIC ENERGY CONVERTERS. Am. Phys. Soc. Bull. 6:385, June 22, 1961.

Abstract only of paper given at the Summer meeting of the American Physical Society, Mexico City, June 22-24, 1961.

"The theoretical efficiency of high-vacuum, thermionic-energy converters with usual emitter materials is calculated. It is shown that the optimal temperature for conversion and the normal operating temperature of the emitter are nearly the same for low work function emitters. Comparison is made with energy converters containing a low pressure noble gas filling. By partly ionizing the gas, space charge is compensated and the efficiency in comparison with high-vacuum converters may be increased considerably." Entire item quoted.

2194
General Electric Co. Vallecitos Atomic Laboratory, Pleasanton, Calif. CALCULATION OF THE MAXIMUM EFFICIENCY OF THE THERMIONIC CONVERTER, by J. H. Ingold. 15p., Dec. 1959. (Rept. GEAP-3283) (Rept. R59APE38)

An analysis of the efficiency of a thermionic converter was made in terms of the potential difference V_a between the top of the potential barrier in the interelectrode space and the Fermi level of the anode, the potential drop, V_L, across a load impedance in series with the converter, and the potential drop, V_l, in the necessary electrical connection to the cathode. It was concluded that low value of V_a is required for high efficiency and relatively low values of V_c are required for maximum efficiency at ordinary cathode temperatures. A guide was prepared which gives the optimum values of the appropriate parameters required for maximum efficiency.

2195
Ingold, J. H. CALCULATION OF THE MAXIMUM EFFICIENCY OF THE THERMIONIC CONVERTER. J. Appl. Phys. 32:769-772, May 1961.

This paper discusses the optimum values of the appropriate parameters which will allow a thermionic converter to be operated at maximum efficiency at a given cathode temperature.

2196
Nottingham, W. B. A SIMPLIFIED METHOD FOR THE COMPUTATION OF THE ELECTRICAL PROPERTIES OF A CLOSE-SPACED THERMIONIC CONVERTER. In Conference on Physical Electronics, 20th. Report, p. 58-69, Cambridge, Mass., Massachusetts Institute of Technology, 1960.

The method depends on the application of accurate equations that permit the designer to introduce all of the important factors which are: (1) the emitter temperature; (2) the diode spacing; (3) the collector work-function; and (4) the emitter work-function.

2197
Schock, Alfred. OPTIMIZATION OF EMISSION-LIMITED THERMIONIC GENERATORS. J. Appl. Phys. 32:1564-1570, Aug. 1961.

Equations are derived describing the performance of space-charge neutralized thermionic converters with negligible transport effects. For a given anode work function and cathode temperature, optimization of the other system parameters leads to an expression for the maximum attainable conversion efficiency, in terms

of the fundamental physical constants, e, m, c, and k. The calculated results, presented graphically, suggest several distinct modes of high-efficiency operation, and lead to a number of interesting conclusions about converters with cesium coated cathodes. With electrodes having a thermal emissivity equal to that of hot tungsten, efficiencies in excess of 30% are shown to be possible.

2198
Webster, H. F. CALCULATION OF THE PERFORMANCE OF A HIGH-VACUUM THERMIONIC ENERGY CONVERTER. J. Appl. Phys. 30: 488-492, Apr. 1959.

The performance of a high-vacuum thermionic energy converter was evaluated from Langmuir's 1923 paper on the thermionic diode. The results are presented in the form of a generalized set of curves which show output voltage as a function of current drawn from the device. These general curves were then applied to a few specific cases to determine what cathode-anode spacings, and cathode and anode properties will be required to produce a practical energy converter.

F. Devices

2199
Beller, William. DOOR OPEN TO LOW-TEMPERATURE THERMIONICS. Missiles & Rockets 9:24-25, Jly. 31, 1961.

FICO-built converter spells longer life for cells using readily available materials; a step toward noiseless subs.

2200
Bernstein, W. LOW-TEMPERATURE THERMIONIC ENERGY CONVERTER. Am. Phys. Soc. Bull. 6:358, June 22, 1961.

Abstract only of paper presented at 1961 Summer meeting of the American Physical Society, Mexico City, June 22-24, 1961.

"In order to achieve high output currents (10 amp/cm^2) in thermionic energy converters, the electron space charge must be neutralized. Consideration of ionization efficiency shows that the usual plasma production method through contact ionization of cesium vapor at the hot cathode, is insufficient to produce the required plasma density at the desirable operating temperature of 1500°K. A simple method for the production of a plasma of the required density in the interelectrode space will be given. It will be shown that the power required to maintain the plasma represents about 5% of the output power of the device. This method of plasma generation can permit relatively low temperature (1500°K) operation at about 25% conversion efficiency at 10 w/cm^2 output power. The problems of producing satisfactory cathodes and 1.0 ev work function anodes will be discussed. Preliminary experimental results which show that adequate space-charge neutralization can be attained will be given". Entire item quoted.

2201
Berry, E. R. EFFECT OF ELECTRICAL AUGMENTATION ON NUCLEAR ROCKET FLIGHT PERFORMANCE. ARS J. 31:92-94, Jan. 1961.

A specific example of the transmission of electrical power from a propulsion reactor to the working fluid is evaluated. Such a scheme increases the specific impulse of a nuclear rocket but imposes a dead weight increase for electrical equipment. In the case studied, thermionic converters produce an arc discharge in the hydrogen working fluid. Arbitrary and approximate assumptions are made, but the effect of them on the results is not considered significant. Other working fluids were considered: Li, LiH, NH_3, and H_2O. It appears that unless heat-to-power conversion equipment lighter than 0.005 lb/ekw can be developed, electrical augmentation offers no advantage. (Nuclear Sci. Abs. 15:10543, 1961)

2202
Carabateas, E. N., Pezaris, S. D. and Hatsopoulos, G. N. INTERPRETATION OF EXPERIMENTAL

CHARACTERISTICS OF CESIUM THERMIONIC CONVERTERS. J. Appl. Phys. 32:352-358, Mar. 1961.

Experimental V-I curves have been obtained from a 150-w cesium thermionic converter. Two different kinds of V-I curves can be clearly distinguished. One corresponding to a collision-free type operation, is obtained when the cesium mean free path is of the order of three or more times the interelectrode spacing. The other, corresponding to a sheath-type operation, is obtained when the spacing is of the order of 30 cesium mean free paths. In the first case the log I vs V plot has the familiar shape observed by Hernqvist et al, (RCA Rev. 19:244, 1958); it consists of two straight lines meeting at the breakoff point. From such an experimental curve the difference in emitter and collector work functions and the emitter temperature can be readily obtained. In the second case the V-I curve has the standard shape of a sheath curve which is smooth without breakoff point and which shows saturation in the current for both the high positive and high negative value of the voltage. In the present work a method is outlined by means of which the difference in emitter and collector work functions, as well as the emitter temperature, can be determined from an experimental V-I curve of the second kind. With this method experimental data from the above-mentioned converter in sheath-type operation has been successfully analyzed, and good agreement has been obtained between experimental results and theoretical predictions.

2203
DIRECT A-POWER ELECTRICITY WITHOUT USING STEAM TURBINE: PLASMA THERMOCOUPLE. Elec. Eng. 78:717, June 1959.

Reference is made to a "gadget" that turns the energy of splitting atoms directly into electricity inside an atomic pile.

2204
DIRECT HEAT TO ELECTRICITY. Mech. Eng. 80:67, Jan. 1958.

The thermionic converter developed by General Electric is the subject of this news item. The primary difference between the converter and a thermocouple is that in the converter the metals are separated by a gas at very low pressure. This results in an increase in efficiency, because while there is an electrical flow between the cathodes there is less heat flow than between metals. Efficiencies up to 30% are anticipated.

2205
Eitel-McCullough, Inc., San Bruno, Calif. THERMIONIC CATHODES AND THEIR ENVIRONMENT, by E. A. Coomes. 74p., illus., Sept. 1955. (AD-78 498)

A series of discussions is presented on: (1) basic ideas concerning thermionic emitters and emitting materials; (2) cathode patchiness, its effect on emission and emission measurements; (3) a critical review of practical emitters; (4) vacuum attainment and measurement; (5) alkaline earth oxide cathodes, coatings and processing; (6) alkaline earth oxide cathodes, base metals and interfaces; (7) alkaline earth oxide cathodes, pore conduction and complete cathode action; (8) alkaline earth oxide cathodes, activation, emission level, and stability; (9) thoria cathodes, dispenser cathodes, and matrix cathodes; and (10) lanthanum hexaboride and rare earth oxide mixtures as practical thermionic emitters.

2206
Gabor, D. A NEW THERMIONIC GENERATOR. Inst. Elec. Engrs. J. 7:287-288, May 1961.

A thermionic generator capable of producing alternating current is described in this short account. The new generator differs in several respects from previous models developed in the United States by various authors. It does not require

cesium (a chemically very active and difficult vapor that so far has been exclusively used because of its low ionization potential) to achieve full space-charge compensation at a lower cost, but uses argon, with an ionization potential four times higher.

2207
Gabor, D. A THERMIONIC GENERATOR. Power Eng. 2:36-40, May 1961.

The efficiency of a thermionic generator can be raised to a practicable level by supplying positive ions to the hot electrode. Problems of metallurgy, optimum size, etc., are discussed and comparison is made between theory and practice. With further development, the thermionic and the steam generator can be used together. (Fuel Abs. & Current Titles 2:4364, Jly. 1961)

2208
General Electric Co. Research Laboratory, Schenectady, N. Y. A CALCULATION OF THE PERFORMANCE OF A HIGH-VACUUM THERMIONIC ENERGY CONVERTER, by H. F. Webster. 21 p., Nov. 1958. (Rept. 58-RL-2129)

The performance of a high-vacuum thermionic energy converter has been evaluated from Langmuir's 1923 paper on the thermionic diode. The results are presented in the form of a generalized set of curves which show output voltage as a function of current drawn from the device. These general curves have then been applied to a few specific cases to determine what cathode-anode spacings, and cathode and anode properties will be required to produce a practicable energy converter.

2209
General Electric Co. Research Laboratory, Schenectady, N. Y. A CESIUM VAPOR THERMIONIC CONVERTER USING A THORIUM DISPENSER CATHODE, by J. M. Houston. 11p., May 1960. (AFCRL 253) (Sci. Rept. 1) (Contract AF19 (604)5472 (AD-260 357)

A thermionic converter was tested which consisted of a cylindrical, 13.3 cm^2 thorium-dispenser cathode space 1 mm from a copper or fernico anode.

2210
General Electric Co. Research Laboratory, Schenectady, N. Y. CROSSED-FIELD THERMIONIC CONVERSION, by P. H. Peters. 22p., figs., Mar. 1961. (AFCRL-401) (Sci. Rept. 10) (Contract AF19 (604)5472) (AD-260 356)

An experimental study of an electron beam of the crossed field type for use in a thermionic energy converter having three electrodes: an emitter, a collector, and a beam-forming anode.

2211
General Electric Co. Research Laboratory, Schenectady, N. Y. TESTS OF A CESIUM THERMIONIC CONVERTER DESIGNED TO UTILIZE SOLAR ENERGY IN OUTER SPACE, by V. C. Wilson and J. Lawrence. 13 p., Aug. 1960. (Sci. Rept. 3) (AFCRL-281) (Contract AF19(604) 5472)

A cesium thermionic converter with an integral radiator for solar application has been designed and tested. Design, construction and processing techniques are discussed. Performance data under various operating conditions are given including a maximum output power at 1800°C of 85 watts with 15% efficiency. The electric generator and reject heat radiator weighs 7.5 lbs per kilowatt of output electricity.

2212
General Electric Co. Research Laboratory, Schenectady, N. Y. VACUUM THERMIONIC ENERGY CONVERTER, by J. E. Beggs. 13 p., Jly. 1960. (Sci. Rept. 2) (Contract AF19(604)5472) (AD-260 358)

The utilization of materials and techniques employed in building electron tubes for use at high ambient temperatures and in high density nuclear fluxes provide a

basis for the construction of a high vacuum thermionic converter.

Heat is applied to the external surface of one electrode of the converter. The interior surface of this hot electrode operates in a vacuum and is coated so that it is capable of emitting copious numbers of electrons. The other electrode of the converter has a coating on its interior surface that can provide a low anode work function so as to increase the energy available to an external load.

The output and efficiency of a vacuum thermionic energy converter improve as the emitter is heated hotter and as the electrodes are spaced more closely. At an emitter temperature of 1100°C an output of 1 watt/cm^2 and efficiency of 4.5% have been attained.

In practical applications heating can be accomplished by the use of chemical fuel, solar radiation, or nuclear energy.

2213
Hatsopoulos, G. N. SOLAR HEATED THERMIONIC CONVERTER. 13p., illus., New York, United Nations, May 5, 1961. (E/CONF. 35/S/78)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

Principles of operation, advantages and uses in the direct generation of electricity from solar energy are delineated.

2214
Hatsopoulos, G. N. and Welsh, J. A. THERMIONIC CONVERTERS FOR THE DIRECT GENERATION OF ELECTRICITY FROM GAS. Paper given at 8th International Gas Conference, Stockholm, 1961. (Paper IGU/21-61)

The paper describes the principles of operation of converters and gives an analysis of the engineering problems arising from the use of gas as a fuel. Solutions to these engineering problems are discussed and a conceptual design is presented. Some of the immediate and future applications of the thermionic converter are discussed. (Fuel Abs. & Current Titles 2:4367, Jly. 1961)

2215
Hernquist, K. G. THERMIONIC CONVERTERS. In Power Sources Conference. Proceedings, 14th, p. 7-10, Red Bank, N. J., PSC Publications Committee, 1960.

The present version of the cesium vapor type thermionic converter calls for heat source temperatures in excess of 2000°C. Some of the construction and application problems for this type of converter are discussed. Considerable progress towards solving these problems for solar, chemical, and nuclear energy applications are demonstrated.

2216
HIGH-VACUUM THERMIONIC CONVERTER. Frank. Inst. J. 266:255-256, Sept. 1958.

This news item concerns the diode developed by General Electric which utilizes a combination of metal and ceramic discs surrounding a high vacuum. This is in contrast to the V. C. Wilson design which was gas-filled. The internal resistance problem is solved by placing the electrodes very close together.

2217
Houston, J. M. A CESIUM VAPOR THERMIONIC CONVERTER USING A THORIUM DISPENSER CATHODE. In Conference on Physical Electronics, 20th, Report, p. 72-75, Cambridge, Mass., Massachusetts Institute of Technology, 1960.

A report is given of current-voltage characteristics and power output.

2218
Howard, R. C. A NUCLEAR-THERMIONIC CONVERTOR. Inst. Elec. Engrs. J. 7:284-286, figs., May 1961.

In April 1960 a nuclear-heated thermionic diode, consisting of a

uranium carbide cathode and copper anode, produced 90W of electricity at efficiencies and power densities adequate for practical applications. In this article, the author gives a short account of this thermionic cell, which he considers gave very promising results.

2219
Kaplan, Coleman. THE PLASMA DIODE SPACE POWER SYSTEM. Remarqs 1:6-9, Fall 1960.

Description of a device for the direct conversion of heat, supplied by nuclear fission, to electricity. The diode cell consists of a cathode, containing a uranium carbide fuel pin, and a surrounding anode; the two electrodes are separated by a gap filled with cesium vapor. The system meets weight and life expectancy requirements for electrical propulsion power sources. Applications to space power systems are discussed. The article is illustrated by cutaway drawings. (Intern. Aerospace Abs. 1:61-3258, May 1961)

2220
Leo, B.S. THE THERMIONIC ENERGY CONVERTER—A PROMISING HEAT ENGINE. Power Eng. 65:49-51, May 1961.

Describes low-voltage high direct-current device, which operates with a cathode temperature of 1200-2000°K and an anode temperature less than 1000°K, depending on the work function, since a low anode work function requires a low anode temperature to prohibit electron emission from the anode. (Battelle Tech. Rev. 10:824, Aug. 1961)

2221
National Aeronautics and Space Administration, Washington, D.C. ANALYSIS OF MAGNETIC TRIODES FOR DIRECT-ENERGY CONVERSION HAVING FLAT-PLATE CATHODES AND ANODES AT AN ARBITRARY ANGLE, by J. E. Hatch. 22p., Nov. 1960. (Tech Note D-575)

Study giving a solution to the equations of motion of the electrons for triodes having flat-plate cathodes and anodes at an arbitrary angle, and having crossed electric and magnetic fields. The magnetic field distribution required to cause electrons that are emitted normal to the cathode to follow circular paths around a common center is determined with the assumption of negligible effect of space charge upon the electric-field potential distribution. With this distribution, collisions of electrons with each other and with the grid may be reduced. Two configurations of a magnetic triode for conversion of heat to electricity are analyzed. (Intern. Aerospace Abs. 1:61-2389, Apr. 1961)

2222
NEW DEVICE DIRECTLY CONVERTS HEAT ENERGY INTO ELECTRIC POWER: THERMIONIC CONVERTER. Indus. Labs. 9:75, Jan. 1958.

Brief article on the thermionic converter invented by Dr. Volney C. Wilson.

2223
Ranken, W.A. and Teatum, E.T. BEHAVIOR OF A THERMIONIC PLASMA CONVERTER WITH A $(UC)_{0.3}(ZrC)_{0.7}$ EMITTER. Am. Phys. Soc. Bull. 6:371, June 22, 1961.

Abstract only of paper presented at Summer meeting of the American Physical Society, Mexico City, June 22-24, 1961.

"A cesium plasma cell, having a $(UC)_{0.3}(ZrC)_{0.7}$ emitter incorporated into a plane parallel geometry, has been constructed and tested. The collector of this cell has an area approximately 10% that of the emitter and is surrounded by an annular guard ring. Measurements which have been made include the determination of the dependence of short circuit current, open circuit voltage, and positive ion current on cesium vapor pressure and emitter temperature. The data give evidence that for a cesium vapor pressure on the order of 2×10^{-3} mm Hg and for

emitter temperatures above 2200°K, the mode of ion formation changes abruptly from an effect best described by the modified Saha equation and characterized by fractional ionization values of less than 10%, to an effect characterized by fractional ionization values on the order of 50% to 100%, with apparent electron temperatures on the order of 6500°K." Entire item quoted.

2224
Saldi, I. T. POWER OUTPUT AND EFFICIENCY OF THERMIONIC CONVERTERS. Inst. Radio Engrs. WESCON Convention Record 4(Pt. 3):3-12, 1960.

Gives a summary of recent work at the American General Electric Co. on thermoelectron engines. With close-spaced diodes power outputs of 0.4 W/cm^2 have been obtained with improved cathodes, smaller electrode spacings and lower anode work functions. This corresponds to a thermal efficiency of about 4%. Efficiencies can be improved by thermal staging and it is thought that efficiencies of 16-25% may be achievable using a cesium-vapor-filled diode in conjunction with a thermoelectric generator. (Sci. Abs. 64B:621, 1961)

2225
Sullivan, L. T. THERMIONIC POWER BECOMES OF AGE. Signal 16:17, 20 Oct. 1961.

Examination of recent developments indicates the arrival of thermionic converters as a practical power source.

2226
THERMIONIC CONVERTER RUNS ON EVERYDAY FUELS. Mach. Design 33:8, illus., Apr. 27, 1961.

Recent advances in materials technology and a new sealing technique are the developments said to have made the new GE thermionic converter feasible. The device is predicted to be especially attractive as a space-power system because it is rugged and needs no auxiliary cooling.

2227
THERMIONIC CONVERTERS NEAR MARKET. Missiles & Rockets 7:15, Sept. 5, 1960.

Practical thermionic converters are being produced in quantity by GE and are expected to be on the market in October 1960.

2228
TUBES CONVERT HEAT: THERMIONIC CONVERTER. Electronics (Bus. ed) 30:29, Dec. 10, 1957.

This is essentially a news item about the GE thermionic converter which is reported to have an 8% efficiency compared with thermocouples with less than 1% efficiency. Metals in the GE converter are separated by ionized gas at low pressure. One electrode is held at 2500°F. This reduces the space charge around the emitter and increases the efficiency of the converter. The intense heat of guided missiles may one day be used in converters for powering guidance and telemetering equipment.

2229
Westinghouse Electric Corp., Elmira, N. Y. AN INVESTIGATION OF GAS-FILLED THERMIONIC CONVERTERS FOR TRANSFORMING FISSION HEAT INTO ELECTRICITY, by G. R. Feaster. 1 vl. illus., Oct. 15, 1960. (Interim Sci. Rept. 1) (Contract AF33(616)7198) (AD-251 524)

Attention was directed toward a survey of the state-of-the-art and experimental work on plasma diodes, with some theoretical work on plasma oscillations. In the survey no plasma diode converter was found with an actual efficiency of as much as 10%. Computed efficiency lies in the range of 10 to 15%. The survey showed that efforts are being directed toward the attainment of good

efficiency at reduced cathode temperatures. Experimental work at the two Westinghouse organizations has included the following items: (1) Effect of different cathode-anode spacing: (2) Effect of gases on cell operation: (3) Effects of variations in cathode temperature, anode temperature, and cesium pressure: (4) Data were taken on plasma oscillations: (5) Performance with rubidium fill in place of cesium: (6) Moderately sophisticated test vehicles were designed, tooled for and built; and (7) A device for imaging a cesium-film-on-tungsten emitter was built and preliminary observations were made. Analysis of the possibility of using a gamma or neutron flux to provide ionization of an inert gas fill was made, with the former proving to be impractical and the latter a marginal possibility.

2230
Wilson, V. C. THE CONVERSION OF SOLAR ENERGY TO ELECTRICITY BY MEANS OF THE THERMIONIC CONVERTER. 19p., illus., New York, United Nations, May 12, 1961. (E/CONF. 35/S/90)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

The operation of various types of thermionic converters is described and the possibility considered of utilizing thermionic converters to generate inexpensive electricity from solar energy.

G. Systems

2231
Beller, William. "STEPS" SOLAR-POWER SYSTEM TO BE TESTED SOON. Missiles & Rockets 8:22-23, illus., June 5, 1961.

Called "STEPS", an acronym for Solar Thermionic Electric Power System, it is being built by GE for the Air Force. It is composed of a collector - a parabolic reflector - which focuses the sun's rays on a generator made up of many thermionic converters, and several subsystems, and is designed to operate with nickel-cadmium battery storage.

2232
General Atomic, San Diego, Calif. PARAMETRIC STUDY OF THERMIONIC-NUCLEAR ELECTRICAL POWER SOURCE EMPLOYING NON-BOILING NATURAL-CIRCULATION WATER COOLING, by J. Dunlay and F. R. MacDonald. 76p., Aug. 7, 1961. (Rept. 2170) (Contract Nonr-3371(00)) (AD-261470)

Parametric nuclear and heat-transfer calculations are presented which establish approximate values of critical fuel loadings and core diameters for Navy-oriented thermionic-nuclear power sources in the electrical output range from 500 kw to 10 Mw. The nuclear cores consist of an array of cylindrical fuel elements utilizing light water as the coolant, moderator, and reflector. Each fuel element contains a grouping of series-connected thermionic cells arranged axially within the fuel-element cladding. Natural circulation, nonboiling cooling is considered. Two source configurations are selected that represent, at the present time, best estimates of the design parameters compatible with electrical power outputs of 1 and 10 Mw.

2233
General Electric Co. Missile and Space Vehicle Department, Philadelphia, Pa. THERMAL ENERGY STORAGE RESEARCH AND DEVELOPMENT PROGRAM. Interim Report, December 6, 1960 to May 1, 1961, by E. F. Batutis. 50 p., May 1961. (Contract NAs-5-826)

A program is reported to provide a thermal energy storage material (TES) which will store 200 watt-hours per pound when used with a solar thermionic electrical power system at 1600° to 2100° K.

2234
Henderson, R. E. and Dresser, D. L. THERMIONIC CONVERTERS FOR SPACE POWER SYSTEMS. . Soc.

Automotive Engrs. J. 69:72-77, illus., Aug. 1961.

Two types of thermionic converters are being considered for solar thermionic systems to provide electrical power for space vehicles: the vacuum diode and the vapor diode. To illustrate the application of both these types, two systems are described. The first illustrates the use of the vacuum diode in a system for a low orbit satellite mission. In the second, the vapor diode is used in a system designed as a Mars space probe. Based on SAE Paper 350C.

2235
Howard, R. C. THERMIONIC REACTOR SYSTEMS. Nuclear Sci. & Eng. 10:173-182, figs., June 1961.

Thermionic cell development is progressing at such a rapid rate that some of the data required for incorporation of thermionic converters into reactor systems is already becoming available. Although such information is not yet sufficient for detailed design and performance evaluation of nuclear-thermionic systems, it is adequate for preliminary analysis. As more experimental information is obtained, these preliminary analyses will have to be reviewed and the concepts reevaluated. However, they have already shown the interesting potential of—and the severe problems to be overcome in—applying nuclear-thermionic systems in space, marine, and central-station power plants. In this article, the possible concepts for utilizing thermionic cells with nuclear reactors are reviewed and the feasibility of their applications is discussed.

2236
Miller, Barry. NUCLEAR-THERMIONIC POWER UNIT PROPOSED. Aviat. Wk. 75:61, 63, 65, illus., Jly. 10, 1961.

The powerplant, called STAR (Space Thermionic Auxiliary Reactor), is intended to satisfy the electric power needs of avionic and instrumentation gear of future manned and unmanned space vehicles. The STAR concept envisions a cylindrical power supply comprised of a number of repetitive series-connected rings each containing thermionic diodes, fuel elements, and reflectors. Specific power requirements can be satisfied by adding enough rings to produce the desired power.

2237
THERMIONIC CONVERTER UNDER CONSTRUCTION. Missiles & Rockets, 8:23, June 19, 1961.

"A solar-thermionic converter system, designed to generate 135 watts, will be developed by Electro-Optical Systems for NASA's Mariner-class spacecraft. The 25-lb unit, called SET (Solar Energy Thermionic Conversion System), will employ several cesium-vapor thermionic diodes for the energy conversion. A 5-ft diameter solar concentrator will direct radiation to a cavity housing the diode array. First model is due in six months." Entire item quoted.

2238
U. S. Air Force. Wright Air Development Center. Wright-Patterson Air Force Base, Ohio. WEIGHT OPTIMIZATION OF A SOLAR OR NUCLEAR MECHANICAL CONVERSION SYSTEM, by Leon Schipper. 50p., illus., June 1959.

Energy conversion systems for space craft must provide required power with minimum weight. Parameters are investigated for obtaining optimum weight. Efficiency of a component, group of components, or the entire system is important only insofar as it minimizes overall system size and weight. Basic parameters are established for a solar-powered system and specific values assigned. The effect of varying the parameters contributing to efficiency versus system weight are noted. The variables contributing most to system size and weight are collector and radiator. For a nuclear-powered system, the radiator is the only variable providing a possibility of significant weight reduction. By properly matching the

parameters affecting the power-producing unit with parameters affecting the heat-rejecting unit, optimum system weight can be achieved. (Solar En. 4:42, Oct. 1960)

2239
WORK BEGINS ON PLANET PROBE POWER SOURCE. Electron. 34:32, Jly. 7, 1961.

"Payload power source for Mariner-class planetary probes may be a so solar energy thermionic conversion system (SET) now being developed by Electro-Optical Systems, Inc., for the National Aeronautics and Space Administration...

"SET will consist of a lightweight solar concentrator five feet in diameter which will focus solar radiation into a cavity used to heat several cesium vapor-filled thermionic diodes. These diodes will transform heat into electrical current.

"The thermionic generator will consist of an array of diodes arranged about the cavity. The generator will be developed under subcontract by Thermo-Electron Engineering Corp.

"The system will generate 135 watts at a solar constant 40 percent of that available on earth. Total weight of the system will be approximately 25 lb. First prototype model is scheduled for completion in six months." Entire item quoted.

IV. PHOTOELECTRIC PROCESSES
A. Photovoltaic
1. Theory

2240
Anderson, S. SOME POSSIBILITIES FOR SOLAR ENERGY UTILIZATION BY MEANS OF THE PHOTOGALVANIC EFFECT. In Conference on Solar Energy: The Scientific Basis, 4p., Tucson, Ariz., 1955.

The three most frequently employed experimental arrangements for producing photopotential are described, and their possibilities for solar energy utilization examined. A modification of one of them seems promising as a solar energy storage cell although the efficiency would be rather low.

2241
Bachowsky, J., et al. PHOTOVOLTAIC EFFECT CAUSED BY X-RAYS AT p-n JUNCTIONS IN GERMANIUM. Czechoslov. J. Phys. 4:98, 1954.

Letter. With an inverse current through the junction, the change of current was up to 10^3 times the standing current observed on X-irradiation. This change was a slow one, so that secondary processes are probably involved, as well as the primary one of X-ray quantum absorption followed by the production of about 10^4 hole-electron pairs.

2242
Becquerel, E. ON ELECTRIC EFFECTS UNDER THE INFLUENCE OF SOLAR RADIATION. Acad. Sci. Paris. Compt. Rend. 9:561, 1839.

In French. Early historical reference.

2243
Blocher, J. M., Jr. and Garret, A. B. THE PHOTOVOLTAIC EFFECT. THE SPECTRAL SENSITIVITIES OF CADMIUM, ZINC, AND SILVER ELECTRODES: THE EFFECT OF pH AND OXYGEN. Am. Chem. Soc. J. 69:1954-1958, Jly. 1947.

The spectral sensitivity curves have beendetermined for some photovoltaic cells of Cd, Zn, and Ag electrodes. The effect of pH on Ag electrodes is thought to be secondary. The effect of dissolved oxygen has been found to be great, reversing the sign of the photopotential in some instances.

2244
Cummerow, R. L. THE THEORY OF ENERGY CONVERSION IN p-n JUNCTIONS. In Conference on the Use of Solar Energy-The Scientific Basis, vl.5, Tucson, A., 1955. Transactions vl. 5, p. 57-64, Tucson, University of Arizona, 1958.

The theory of energy conversion in p-n junctions is developed and the theoretical efficiencies for a silicon solar energy converter are shown graphically. Some reasons why it is not as efficient in practice are given.

2245
Electro-Optical Systems, Inc., Pasadena, Calif. INVESTIGATION OF COMPOSITE OR STACKED VARIABLE ENERGY GAP PHOTOVOLTAIC SOLAR ENERGY CONVERTER. Final Report. 87 p., Aug. 31, 1960. (Rept. 400-Final) (Contract DA36-039-sc-85244) (AD-253 484) (PB 149 706)

A theoretical analysis is given of the performance of composite photovoltaic solar energy converters consisting of two separate p-n junction cells of differing energy gaps. The analysis considers the spectral efficiencies of the separate cells and the effects of saturation currents as a function of energy gaps.

On the basis of the analysis, Si is chosen for the lower-energy-gap component of the composite cell, and AlSb and CdSe are selected as possible materials for the higher-energy-gap component. The purification of Al and the growth of crystals of AlSb are described in detail. A description is also given of the preparation of crystals of CdSe, but neither AlSb nor CdSe were prepared with sufficient purity to warrant solar cell fabrication.

2246
Feinberg, R. PHOTOELECTRIC RESPONSE OF SELENIUM TYPE PHOTOVOLTAIC CELLS TO X-RAYS. Nature 181:1057, 1958.

A commercially available selenium type photovoltaic cell was irradiated with x-rays, produced with a commercial type of low voltage x-ray tube with a thermionic cathode and an inclined copper target. Lead covers with circular aperatures of different diameters were placed over the photocell to alter the flux of x-rays on the surface of the cell at a constant x-radiation intensity, and the x-radiation intensity was varied by changing the anode current of the x-ray tube.

2247
Hahnlein, A. SEMICONDUCTOR TYPE CONVERTERS OF SOLAR ENERGY. NTZ 9:145-150, illus., Apr. 1956.

In German. Physical fundamentals of photon absorption by semiconductors, particularly of the electron-defect separation by p-n transistions. Analytical results are given on the efficiency of p-n cells in monochromatic and sunlight; possible improvements of the efficiency, and equivalent series and parallel circuits of cell arrangements. The considerations are illustrated by reference to the solar energy converters designed at Bell Laboratories.

2248
Harten, H. U. and Schultz, W. INFLUENCE OF DIFFUSION LENGTHS AND SURFACE RECOMBINATION ON THE PHOTOVOLTAIC EFFECT IN Ge. Z.Physik 141:319-334, 1955.

In German. A theoretical and experimental study of the properties of photovoltaic cells consisting of a thin gold layer on the surface of a germanium crystal. When thick germanium crystals are used, the sensitivity is determined primarily by the minority carrier diffusion lengths. In thin crystals cells the recombination velocity at the free surface of the Ge determines the sensitivity.

2249
Jensen, A. S. and Limansky, Igor. PHOTOELECTRIC CONVERSION. In Power Sources Conference, Proceedings, 14th, p. 46-49, Red Bank, N. J., PSC Publications Committee, 1960.

Photoelectric conversion as a method of utilizing solar energy is treated in detail. Analysis of the photoelectric effect shows that close spacing of the cathode and anode, low work function for the anode, and screening the anode to keep it in the dark can be used to make a low-impedance generator

with useful efficiency. Utilization of the solar spectrum by photogenerators with antimony-cesium photocathodes is examined; a photogenerator with a spacing on the order of 2 mils should be illumination-limited and unaffected by space charge. The practical aspects of photogenerator design are next considered, and performance curves are presented for the WX-3964 photogenerator. Photogenerators have the advantages of simple design and low specific weights and can be fabricated in balloon shape for use as space power sources. (Nuclear Sci. Abs. 15: 11864, 1961)

2250
Kallman, H. and Pope, M. PHOTOVOLTAIC EFFECT IN ORGANIC CRYSTALS. J. Chem. Phys. 30:585-586, Feb. 1959.

In studies on the photoconductivity of anthracene, photovoltaic measurements on thin single crystals were made which appeared to be related to the studies on organic compounds involved in photosynthesis by Calvin and Kearns. One unusual aspect was the electrode configuration and composition when the anthracene crystal was positioned between and separated two 0.01 M NaCl solutions, which acted as transparent electrical contacts with each face of the crystal. An oxidation-reduction reaction appears to take place at the solution-crystal interfaces, and the splitting of water is accomplished by 3650 A light through the intervention of the crystal.

2251
Kofstad, Per, and Hauffe, Karl. APPLICATIONS OF THEORIES OF SEMICONDUCTING SOLIDS TO INDUSTRIAL RESEARCH PROBLEMS. IV. Tids. Kjemi Berguesen Met. 16:51-59, 1956

Not examined. Application of theories of semiconducting solids to problems such as sintering, development of solid electrolytes for fuel cells, and solar and radioactive batteries.

2252
Lagrenaudie, J. TRANSFORMATION de L'ENERGIE SOLAIRE EN ENERGIE ELECTRIQUE au MOYEN de PHOTOPILES. (TRANSFORMATION OF SOLAR TO ELECTRIC ENERGY BY PHOTOELECTRIC CELLS). Ann. Mines 144:72-87, June 1955.

In French. Use of semiconductors and photovoltaic effects. Although photoelectric cells cannot approach 100% because the sun is not monochromatic, they are particularly suitable for limited and localized applications, both industrial and domestic.

2253
Levin, I., et al. THE PHOTOVOLTAIC EFFECT. III. J. Chem. Phys. 21:1654-1659, 1953.

Further studies in the range of 200 to 400 millimicrons indicates that magnitude of the photopotential derived from photoactive substances in solution is dependent on the absorption of the solution. The photovoltaic behavior of 38 organic halides and 89 other organic compounds were studied.

2254
McGee, J. D. PHOTOELECTRIC CELLS—REVIEW OF PROGRESS. Inst. Radio Engrs. Trans. CP-5: 2-23, 1958.

A tutorial review of the various devices that exhibit a photoelectric effect. An exposition of the underlying physical principles that produce photoelectric effects is presented.

2255
Madzjalpv, G. and Andreichin, R. THE CLASSIFICATION OF THE PHOTOVOLTAIC EFFECT AND THE ARRANGEMENT OF THE CONTACT POTENTIAL PHOTOVOLTAIC EFFECT. Acad. Bul. Sci. Compt. Rend. 13:135-138, 1960.

In German. A discussion of concepts relating to the classification of the fundamental kinds of photovoltaic effect.

2256
Matijevic, E. PHOTOVOLTAIC PHENOMENA IN ORGANIC

OXIDATION-REDUCTION SYSTEMS. I. BECQUERAL'S PHOTOVOLTAIC EFFECTS IN THE SYSTEM THIONINE-THIOSINAMINE. II. BECQUEREL'S PHOTOVOLTAIC EFFECT IN THE SYSTEM THIONINE-DIETHYLTHIOSINAMINE. Archiv. Kem. 21:1-20, 22-25, 1949.

Not examined. The photopotential of thionine-thiosinamine and the thionine-diethlythiosinamine systems were studied using a platnium electrode in the range of wavelength of 400-700 Mu. The influence of added substances on the equilibruim was determined.

2257
Prince, M. B. SILICON p-n JUNCTION SOLAR ENERGY CONVERTER. In Conference on Solar Energy: The Scientific Basis, 20p., Tucson, Ariz., 1955.

It is shown that silicon is a suitable semiconductor for a solar energy converter. Its efficiency is calculated under the assumption of actual physical conditions (which include series and shunt resistance with the p-n junction) showing a good measure of agreement with experimental results.

2258
Queisser, H. J. and Shockey, William. SOME THEORETICAL ASPECTS OF THE PHYSICS OF SOLAR CELLS. In Snyder, N. W., ed. Energy Conversion for Space Power, p. 317-323, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3)

Emphasis is laid on the hole-electron recombination processes which limit the output voltage of a solar cell. A maximum efficiency can be calculated for the case of minimum recombination which is only the radiative type, as required by statistics. Non-radiative recombination prevents reaching this ultimate efficiency. Proposals are made to predict the current-voltage relationship and the efficiency of a solar cell from first principles with the aid of a theory of recombination processes.

Also issued as ARS Tech. Paper 1293-60, 6p., New York, American Rocket Society, 1960.

2259
Rappaport, Paul. THE PHOTOVOLTAIC EFFECT AND ITS UTILIZATION. In Seminar on Advanced Energy Sources, 1958, Proceedings ...p. 127-137, Fort Monmouth, N. J., 1959? (Contract DA 36-039-SC-78064) (PB 151461) (AD 209301)

Brief history, description of photovoltaic effect, electrical characteristics, experimental results on GaAs, InP and CdTe.

Article with same title also appears in RCA Rev. 20:373-397, 1959; Solar Energy 3:8-18, Dec. 1959; and Engrs. Dig. 21:123, Jan. 1961.

2260
Rothlein, B. J. THE PHOTOVOLTAIC EFFECT OF SURFACE p-n BARRIERS IN GERMANIUM. Phys. Rev. 83:228, 1951.

Surface barriers on germanium can be made having an exceptionally high photovoltaic response. Characteristics of this effect described.

2261
Ruth, R. P. and Moyer, J. W. POWER EFFICIENCY FOR THE PHOTOVOLTAIC EFFECT IN A Ge GROWN JUNCTION. Phys. Rev. 95:562-564, 1954.

Measurements and discussion of observed efficiencies of conversion of incident radiation into power in a resistive load in series with a Ge p-n junction. Power efficiency increases with incident intensity over a large range of intensities in a manner similar to that in which the open-circuit photovoltage varies with incident intensity. It is predicted that a junction with an effective quantum efficiency of nearly unity might develop power efficiencies of 7 or 8%.

2262
Simon, H. and Suhrmann, R. THE PHOTOELECTRIC EFFECT AND ITS APPLICATION. 747 p., Berlin, Springer Verlag, 1958.

In German. This book contains two sections on photoelectric emission and photoconduction, including photovoltaic effects, in relation to their fundamental aspects; preparation techniques for photoelectric cells include purification methods for materials involved; a description of production methods for the various photo conducting and photovoltaic devices; secondary emission and its application in photoelectric multiplier tubes; radiation measurement techniques using the various kinds of detectors inclusive of spectrophotometry; applications to photometry, image intensifiers, television and nuclear particle detection; references to literature are given and there are diagrams and illustrations of devices.

2263
Tauc, Jan. THE THEORY OF A BULK PHOTOVOLTAIC PHENOMENON IN SEMICONDUCTORS. Czechoslov. J. Phys. 5:178-192, 1955.

It is shown theoretically that for a photovoltaic phenomenon in semiconductors to exist neither the presence of localized potential barriers with rectifying properties at the contact of a semiconductor with a metal or a p-n junction nor the presence of non-rectifying contacts is necessary. For this type of "non-barrier and non-contact" photovoltage the name "bulk" photovoltage is proposed.

2264
Tauc, Jan. THE THERMODYNAMICS OF NON-BARRIER LAYER PHOTOVOLTAIC PHENOMENA. Czechoslov. J. Phys. 5:300-304, 1955.

By using quasi-Fermi levels, which have the meaning of partial chemical potentials of an assembly of electrons and of holes, and an analogy with galvanic cells, an equation was derived for the photovoltage of a non-barrier-layer semiconductor photocell on the basis of thermodynamic laws. When classical statistics are applicable, the basic equation leads to the result derived by kinetic considerations. Attention is thus drawn to the application of thermodynamics to photovoltaic phenomena in semiconductors.

2265
Waldner, M. MEASUREMENT OF MINORITY CARRIER DIFFUSION LENGTH AND LIFETIME BY MEANS OF PHOTOVOLTAIC EFFECT. Inst. Radio Engrs. Proc. 47:1004-1005, 1959.

If light is filtered by sufficient thickness of a given semiconductor it may then be used to obtain uniform carrier generation near a p-n junction in a specimen of the same semiconductor. Together with an independent measurement of the minority carrier diffusion distance this gives the charge generation rate of the filtered radiation. Silicon with diffused gallium or boron was investigated. The short circuit photovoltaic current is large enough to measure in samples with $\gamma = 0.1\mu$ sec.

2266
Wysocki, J. J. THE EFFECT OF SERIES RESISTANCE OF PHOTOVOLTAIC SOLAR ENERGY CONVERSION. RCA Rev. 22:57-70, figs., Mar. 1961.

The series resistance in a photovoltaic cell is divided into two components: contact and sheet resistance. Each of the components is examined theoretically and experimentally, and qualitative agreement between theory and experiment is shown. It is concluded that contact resistance reduced the conversion efficiency more than sheet resistance.

2267
Zaidman, N. M. SPECTRAL DISTRIBUTION ON THE PHOTOVOLTAIC EFFECT OF SILVER BROMIDE ELECTRODES. Zhurn. Fiz. Khim. 26:1791-1797, 1952.

In Russian. AgBr electrodes with excess Ag in 3% gelatin solution show a negative photopotential. Its spectral distribution shows 2 bands, one short-wave (I) with two maxima and one long-wave (II). Upon aging I changes little and II increases. AgBr

with excess Br has a positive photopotential. Upon aging Br disappears and the photopotential becomes negative and II increases.

2. Silicon Cells

2268
Admiral Corp., Chicago, Ill. SOLAR CELLS, by Harry Thanos and Roger Weber. 5 p., illus., Aug. 5, 1955. (AD-115 969)

A preliminary investigation was conducted on seven solar cells to see if they can supply sufficient power to operate a small electronic device such as a hearing aid or a small portable radio. These solar cells are made by the Semi-conductor Division of National Fabricated Products and are hermetically-sealed, p-n junction silicon units. The spectral response curve of power versus wavelength for the silicon p-n junction employed in the type S-1 cell shows a broad flat maximum extending from 7000-8500 angstrom units. The half power points are 5500 to 9500 angstroms.

2269
Baum, V. A., Borovikova, R. P. and Okhotin, A. S. SEMICONDUCTOR CONVERTERS OF SOLAR ENERGY. 34 p., figs., New York, United Nations, May 27, 1961. (E/Cong. 35/S/118)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

The paper is a summary of some of the investigations conducted during the past several years at the heliotechnical laboratory of the Power Institute of the USSR Academy of Sciences.

Thermoelectric and photoelectric converters of solar energy are discussed.

2270
Brown University. Dept. of Physics, Providence, R. I. INVESTIGATIONS OF SURFACE PROPERTIES OF SILICON AND OTHER SEMICONDUCTORS. Phase I, by H. E. Farnsworth et al; Phase II, by J. A. Dillon, Jr. and R. M. Oman. 3 issues, Apr. Jly. Oct. 1960. (Sci. Repts. 2, 3, 4) (Contract AF19(604)5986)

For Phase I, experiments with a (111) surface of GaSb and an n-type germanium crystal are reported.

For Phase II, experimental data concerning the formation of p-type films on heat-treated silicon are presented.

2271
Chapin, D. M. SOME OBSERVATIONS FROM A FIRST YEAR OF SILICON SOLAR BATTERY TESTING. In Conference on the Use of Solar Energy--The Scientific Basis, Tucson, 1955. Transactions vl. 5, p.117-121, Tucson, University of Arizona, 1958.

First year of silicon solar battery testing at Murray Hill, N. H. at 40° tilt has shown that: (1) average power ranges from about 1/10th of the peak value in December to about 1/5th in June; (2) for the constant load of 1/10th of the maximum, about 8 days of storage capacity is required while a month's storage will permit about 1/6th of the maximum to be drawn as a continuous load.

2272
Chechik, P. A SOLAR BATTERY. Radio USSR 7:58-59, illus., 1955.

In Russian. Trans. available from LC, no. RT-3166, also from Canada. Defense Res. Bd. Directorate of Sci. Intelligence. Trans. 7. (AD-78 161).

First Russian announcement of a workable solar battery. Data on the battery in this article agrees with that of the Bell model as to efficiency, spectrum position of maximum response, and power output.

2273
Cummerow, R. L. USE OF SILICON p-n JUNCTIONS FOR CONVERTING SOLAR ENERGY TO ELECTRICAL ENERGY. Phys. Rev. 95:561-562, 1954.

Equations are given for monochromatic radiation and the calculations

are extended to the solar spectrum with a silicon p-n junction.

2274
Dale, B. and Rudenberg, H. G. PHOTOVOLTAIC CONVERSION. 1. HIGH EFFICIENCY SILICON SOLAR CELLS. In Power Sources Conference. Proceedings, 14th, 1960, p. 22-25, Red Bank, N. J., PSC Publications Committee, 1960.

Improvements made in high efficiency silicon solar cells under a research study have been described. They have raised the overall conversion efficiency of the units from 10% to 15%, by careful design of the cell structure. The work has raised the output voltage of the cell, substantially lowered the series resistance, and has provided various surfaces with differint optical characteristics. A five-cell array capable of 1 watt output in bright sunlight is now possible.

2275
Dale, Brian and Smith, F. P. SPECTRAL RESPONSE OF SOLAR CELLS. J. Appl. Phys. 32:1377-1381, figs., Jly. 1961.

An analysis of the spectral response of a solar cell is given which includes the effect of the electric field present in the diffused surface region. Results are presented which show the variation of response with junction depth and with carrier lifetime in both surface and bulk regions. By curve fitting, it is found that in a typical silicon cell the bulk lifetime is in the range 1-15μsec, while the surface region lifetime is between 10^{-9} and 10^{-19} sec. Bombardment with a total flux of 3.3×10^{14} electrons/cm^2 of 2-Mev electrons reduced the n- region lifetime by a factor of 300, and the p region lifetime by a factor of 6 in a particular case.

2276
Davis, J. I. SOLAR CELL R AND D. Space/Aero. 31:44-46, illus., Apr. 1959.

Next target for solar cell engineers is the two-kilowatt power supply that has been proposed for space vehicles. To reach it, higher efficiencies must be achieved in designs based on the present state of the art.

2277
de Latil, Pierre. L'ELECTRICITE DE L'AVENIR PAR LESS THERMOPILES, PHOTO-PILES, RADIO-PILES. (ELECTRICITY OF THE FUTURE FROM THERMOPILES. PHOTOCELLS, AND RADIO CELLS) Sci. & Avenir no. 135: p. 247-252, May 1958.

In French. Methods of direct generation of electricity, including brief mention of the solar photocell.

2278
Denney, J. M., Downing, R. G., and Grenall, A. HIGH ENERGY PROTON RADIATION DAMAGE. In Snyder, N. W., ed. Energy Conversion for Space Power, p. 363-371, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry vl. 3)

An experiment at the Lawrence Radiation Laboratory is reported consisting of irradiating silicon with monoenergetic 740 Mev protons. Approximately 70 silicon solar cells were irradiated in groups of 5 at a measured temperature of (24±2)°C. Data show that high energy protons create damage in silicon semiconductor devices such as solar cells at a surprisingly rapid rate compared to that expected from extrapolation of low energy data.

2279
Erwin, J. O. and Hammel, Wallace, Jr. THE LIGHT APPROACH TO PATTERNING. Textile Indus. 123:109, 124, 126, 128, illus., May 1959.

Use of the silicon solar cell in tufting machine pattern attachments is explained.

2280
Fuller, C. S. THE BELL SOLAR BATTERY. The Indicator (ACS) 35:54-56, 61, Sept. 1954.

Detailed discussion of the operation of the Bell silicon p-n junction-type battery, with illustrations and diagrams, in good detail.

2281
General Electric Co., Syracuse, N. Y. INVESTIGATIONS OF LARGE AREA PHOTOVOLTAIC SOLAR ENERGY CONVERTERS. Final Report, by J. F. Elliott, R. E. Hysell, and C. L. Kolbe. 50 p., illus., Jan. 28, 1961. (Contract DA 36-039-sc-85286) (AD-253 389)

Polycrystalline silicon films were prepared on various types of substrates by the reduction of $SiCl_4$. These films can be grown to any desired thickness and have grain size of greater than 10 microns. Single crystal films were prepared with resistivities of up to 30 ohm-cm over areas of about 3/4 square inch. These single crystal films are to be used as a basis for understanding the nature of the polycrystalline film. Silicon ingots have been mechanically deformed by extruding and rolling techniques. Samples were prepared having continuous surface areas of greater than 30 square inches by this means. Photovoltaic cells were prepared from both types of material. The cells have short circuits of 20 ma/sq cm, and open circuit voltages of 0.2 volts.

2282
Gianola, U. F. PHOTOVOLTAIC NOISE IN SILICON BROAD AREA p-n JUNCTIONS. J. Appl. Phys. 27:51-54, illus., Jan. 1956.

Certain of the noise characteristics of silicon broad area junctions which have been developed for use for solar energy conversion. Under constant illumination, the photovoltaic output of these junctions has been found to show fluctuations which are characteristic of a 1/f noise power spectrum. For varying illumination, the magnitude of the photovoltaic noise voltage has been found to vary considerably, and in fact passes through a pronounced maximum. A plausible explanation of this effect is obtained by assuming that fluctuations are produced in the primary photocurrent as a result of traversing the junction. The assumption of a current dependent noise mechanism is justified by an independent experiment.

2283
Heeger, A. J. and Nisbet, T. R. THE SOLAR CELL--CONDITIONS FOR OPTIMUM PERFORMANCE. Solar En. 3:12-18, figs., Jan. 1959.

The role of the dark diode curve in solar cell evaluation and circuit design is discussed. A simple graphical method of determining the optimum load resistance of any cell is developed using the diode curve as a basis. Detailed consideration of the diode curve offers insight into the operation of a solar cell, and the general conclusions are stated. The versatility of this method of approach is demonstrated by discussion of the conditions for optimum load when the intensity of illumination is varying. A simple, automatic device for displaying diode curves is described, with details of its use in the evaluation of solar cells.

2284
Hilsum, Cyril. PROGRESS IN DEVELOPING SOLAR BATTERIES. New Scientist 7:96-100, illus., Jan. 14, 1960.

Transistor research has opened up new possibilities of converting the sun's radiation into usable energy. Experiments are continuing with batteries of semiconductor cells - and they are already providing an appreciable source of electric power.

2285
Hoffman, H. L. HARNESSING THE SUN'S ENERGY: CAN IT COMPETE WITH NATURAL FUELS? Trusts and Estates 96:1019-1021, Oct. 1957.

Hoffman Electronic Corporation's development of silicon solar energy converters; high cost of the silicon

used in cells; present utilization to supply power in remote areas and to operate flashlights, radios, etc.

2286
Hoffman Electronics Corp., El Monte, Calif. FORMATION OF SILICON SPHERES FOR THE MULTIELEMENT LARGE-AREA SOLAR CELL, by H. Biekofsky. 3 p., Mar. 20, 1961. (Mon. Ltr. Rept. 1) (Contract DA36-039-sc-87420)

A program for the project is outlined.

2287
Hoffman Electronics Corp., El Monte, Calif. PILOT LINE PRODUCTION OF HIGH EFFICIENCY SOLAR CELLS, by E. L. Ralph and H. F. Biekofsky. 3 issues, Mar. 31, June 30, 1960, Mar. 1961. (Interim Tech. Eng. Repts. 1, 2, and Final) (Contract AF33(600)40497) (AD-235 302, AD-240 000, AD-259 035)

The limitations of silicon solar cells are discussed and four major areas of improvement are considered: optimization of p-layer thickness and series resistance; selection of crystals with improved properties; improved handling and fabrication techniques; decreased losses due to series resistance. Various studies and experiments made in order to obtain higher efficiency solar cells are detailed. Studies are discussed which determined optimum junction depth and diffusion parameters necessary to obtain these junction depths. Several diffusion experiments were performed and the variation of surface concentration, junction depth and the diffusion coefficient have been determined as a function of temperature. The effect of varying diffusion temperature on solar cell spectral response was investigated. Two methods of evaluating diffusions (junction depth and sheet resistance) are analyzed, and experimental techniques for evaluating diffusion by these methods are discussed.

2288
Hunrath, George. SOLID STATE POWER SUPPLIES. Contr. Eng. 8:173-177, illus., Sept. 1961.

Silicon photovoltaic cells and thermocouples can convert solar energy and heat into electrical energy. Both means of energy conversion are potential self-contained power supplies for control and data handling systems. Prime applications have been in satellites and other inaccessible military systems, but isolated examples of industrial use already exist. Device characteristics such as capacity, efficiency, and weight, and system considerations are covered to acquaint control engineers with this new solution to the remote power supply problem.

2289
Jackson, E. E. AREAS FOR IMPROVEMENT OF THE SEMICONDUCTOR SOLAR ENERGY CONVERTER. In Conference on the Use of Solar Energy: The Scientific Basis, Tucson, 1955. Transactions, v1. 5, p. 122-126, Tucson, University of Arizona, 1958.

Methods of reducing losses in the semiconductor solar energy converter are discussed. A novel cell construction is proposed which offers a higher theoretical conversion efficiency than current types.

2290
Kallander, J. W. and Weller, J. F. RADIATION BEHAVIOR OF ELECTRICAL MATERIALS AND COMPONENTS FOR SPACE VEHICLES. Rept. NRL Prog. p. 11-17, illus., May 1961.

Solar cells, ordinary quartz shields, and adhesives for cementing solar cells to satellite skins have been exposed in the laboratory to the kinds of high-energy radiation that would be encountered in space vehicles. The data presented here pertain to electron irradiation and its effect on the electrical characteristics of solar cells and their associated materials. It was found that the initial output of a solar cell

is influenced greatly by the thickness of the shield, that the load characteristics are affected by the darkening of the shield, and that the maximum efficiency decreases as the cell is exposed to larger and larger doses of electron irradiation. Results of studies of epoxy adhesives so far are similar for different samples having the same cure, but vary with the cure - the slower the cure, the more radiation resistant is the adhesive.

2291
Kalman, Jerome. SILICON SOLAR CELLS - TAPPING POWER FROM THE SUN. Electron. Design 9:68-73, Feb. 15, 1961.

Discussion of the state of development in silicon solar cells. Efficiencies of 10 to 14% have been achieved. Cost is still high per cell, but research efforts promise a significant reduction within several years. Advantages and disadvantages of the conversion techniques using batteries, fuel cells, and solar cells are compared. (Intern. Aerospace Abs. 1:61-2393, Apr. 1961)

2292
Kobayashi, Masatsugu. UTILIZATION OF SILICON SOLAR BATTERIES. 16 p., New York, United Nations, Apr. 10, 1961. (E/CONF. 35/8/11)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

Since 1958, many repeater stations and light-houses with solar batteries as the power source have been erected in Japan and they have been operated without any trouble. From the economic point of view, the silicon solar batteries are a very excellent power source in remote places, isolated islands, and space.

2293
Linder, E. G. SOLAR BATTERIES. In Battery Research and Development Conference, 10th, 23 May 1956, Proceedings p. 59-62, Fort Monmouth, N. J. Army Signal Corp Engineering Laboratory, 1956.

The origin and early development of photovoltaic cells from 1839 to the present day; operation of the p-n type solar cell; recent work with solar batteries, since 1954, at the Bell Telephone Laboratories, the General Electric Company and the Wright Air Development Center; cost of commercial batteries, are discussed.

2294
Lockheed Aircraft Corp., Missiles and Space Division, Sunnyvale, Calif. SOLAR CELL MEASUREMENT STANDARDIZATION. 1 vl., illus., Feb. 29, 1960. (Rept. LMSD-288184) (AD-248 062)

Report of the Joint Meeting by the West Coast Sub-Committee of the AIEE Solid State Devices Committee and the Semiconductor Photodiode Task Group (28.4.6) of the IRE Solid State Devices Committee at Los Angeles, California, December 17-18, 1959.

This analysis on solar cell standards and measurements covers the preparation of standard solar cells, methods for measuring the direct solar radiation intensity, the latitude of the observing location, and atmospheric conditions necessary for accurate measurement. Calibration and maintenance of standard solar cells are also included. Laboratory light source and instrumentation of cell measurements are discussed. Definitions are given of the various terminologies, and a literature survey for 1949 to the present is included. A precision radiometer for the measurement of total radiation in selected spectral bands is described and representative solar radiation data are presented.

2295
Loferskii, J. J. A BRIEF RESUME OF RADIATION EFFECTS ON SEMICONDUCTOR MATERIALS AND DEVICES. In Conference on Nuclear Radiation Effects on Semiconductor Devices, Materials, and

Circuits, New York, 1959, Proceedings, p. 8-10, New York, Cowan, 1960.

Transient and permanent radiation effects on semiconductor materials, mainly Ge and Si, and devices are reviewed. Radiation effects on Fermi and energy levels are discussed, and the implications of semiconductor radiation-effect data on transistors, solar cells, and other devices are examined. (Nuclear Sci. Abs. 15:16157, 1961)

2296
Loferski, J. J. and Rappaport, Paul. THE EFFECT OF RADIATION ON SILICON SOLAR ENERGY CONVERTERS. RCA Rev. 19:536-554, figs., 1958.

The performance of silicon solar cells under simultaneous illumination and irradiation by various ionizing radiations has been observed for the purpose of estimating the useful life of such power sources in the environment of the IGY earth satellite. Experiments were conducted both in air and in vacuum for 2 mev electrons, 20 mev protons, and 40 mev alpha particles. The maximum power, open-circuit voltage and short-circuit current experienced a decay. These results have been extrapolated to yield an estimated minimum of about 10^5 years until the output of such cells on a satellite drops to 75% of the initial value.

Possible modifications of these estimates based on tentative data acquired from satellite flights have been considered.

The decay of the cells is associated with changes in minority-carrier lifetime and deviations from expected behavior are discussed. No definite decay was observed during the limited exposure time of this study for the ultraviolet radiation between 2200 A and 3400 A or for x-rays from machines operated at 50-2,000 kilovolts.

2297
Loferski, J. J. and Wysocki, J. J. SPECTRAL RESPONSE TO PHOTOVOLTAIC CELLS. RCA Rev. 22:38-56, illus., Mar. 1961.

This paper presents a theoretical and experimental study of the spectral response of p-n junction photovoltaic cells. The current flowing across the junction is calculated as a function of the absorption constant of the radiation for various values of the semiconductor parameters. The results of machine calculations of practically interesting cases are shown in the figures. The use of normalized spectral-response curves to determine the values of minority-carrier diffusion lengths is demonstrated. It is shown that by using certain approximations it should be possible to determine minority-carrier diffusion lengths on both sides of the junction with relative ease. These principles have been applied to experimental GaAs and silicon photovoltaic cells to determine the values of diffusion lengths in the finished junctions.

2298
Luft, Werner. RANDOMLY ROTATING SPHERICALLY ARRAYED SILICON SOLAR ENERGY CONVERTERS. Solar En. 4:33-39, illus., Oct. 1960.

Since spherical arrays of silicon solar cells are contemplated for the photovoltaic conversion of solar energy in certain satellite projects, various aspects of the solar cell matching problem arising from the nonuniform irradiation and temperature in an unoriented randomly spinning converter are discussed, and a sample calculation of power output is given.

2299
Luft, Werner. UNDERSTANDING SILICON PHOTOCELLS. Electron. Indus. 20:102-105, illus., Feb. 1961.

Silicon photocells offer a number of advantages in data processing equipment and for low-light-level sensing operations. However, for various reasons design engineers are often uncertain about how to use these devices. Here the photocell

characteristics are analyzed and explained.

2300
MAKING THE SUN-POWERED SATELLITE. Bell Tel. Mag. 40:13-15, illus., Summer 1961.

Includes photographs taken at Western Electric's Allentown, Pa. Works where the solar cells are being produced for satellite use.

2301
Mandelkorn, Joseph, Kesperis, James, et al. PHOTOVOLTAIC CONVERSION. 6. COMPARISON OF p-n AND n-p SILICON SOLAR CELLS. In Power Sources Conference. Proceedings, 14th, 1960, p. 42-45, Red Bank, N. J., PSC Publications Committee, 1960.

Preliminary results of a study undertaken at the U. S. Army Signal Research and Development Laboratory are summarized.

2302
Maslakovets, Iu. P., et al. P-SILICON PHOTOELECTRIC SOLAR ENERGY CONVERTERS. Zhurn. Tekh. Fiz. 26:2396-2397, Oct. 1956.

In Russian. Vapor phase diffusion of Sb into p-type Si gave n-p junctions showing a photovoltaic peak response at 700 mμ. One such element, area 1 sq. cm., had the following characteristics in direct sunlight: short circuit current 1-mA, open circuit voltage 450 mv, maximum conversion efficiency 2.8% with 300 mv generated across a 33 ohm load.

2303
Miller, Barry. THIN FILM SOLAR CELL RESEARCH ADVANCES. Aviat. Wk. 75:62-65, 67, illus., Jly. 31, 1961.

An accompanying chart depicts organizations engaged in research, their approach, materials used, status, efficiency of the product, and comments.

2304
National Aeronautics and Space Administration, Washington, D. C. IRRADIATION EFFECTS OF 22 and 240 MEV PROTONS ON SEVERAL TRANSISTORS AND SOLAR CELLS, by W. C. Hulten, W. C. Honaker, and J. L. Patterson, 28 p. Apr. 1961. (Tech. Note D-718)

This report covers proton bombardment effects on electronic components as determined from simulation of two portions of the proton spectrum to be encountered in the earth's trapped radiation belts. The experimental data indicated definite detrimental effects on transistors and solar cells but no apparent damage to the types of resistors and condensers tested. The detrimental effects were of two distinct types: transient and permanent.

2305
Pearson, G. L. CONVERSION OF SOLAR TO ELECTRICAL ENERGY. Am. J. Phys. 25:591-598, Dec. 1957.

A photovoltaic device has been developed which converts solar radiation directly into electrical energy with an overall efficiency of 11%. This consists of a p-n junction formed by gaseous diffusion near the front surface of a silicon plate.

2306
Prince, M. B. LATEST DEVELOPMENTS IN THE FIELD OF PHOTOVOLTAIC CONVERSION OF SOLAR ENERGY. 26 p., illus., New York, United Nations, Apr. 28, 1961. (E/CONF 35/S/65)

Silicon photovoltaic cells have been improved through basic scientific developments so that 12 to 14% conversion efficiencies are obtained in production quantities of these devices. The major improvements have consisted of increasing the lifetime in bulk silicon, introducing gridding techniques for contacts, and reducing the thickness of the diffused layer. Other developments for the purpose of reducing costs for photovoltaic conversion of solar energy include the

investigation of thin film silicon cells, studies of other materials, and increasing the area of silicon solar cells. Comments are made concerning the present and near future cost for photovoltaic energy converters, and two applications are described.

2307
Prince, M. B. PHOTOVOLTAIC CONVERSION. II. LARGE AREA SILICON SOLAR CELLS. In Power Sources Conference. Proceedings, 14th, 1960, p. 26-27, Red Bank, N. J., PSC Publications Committee, 1960.

Several approaches to the production are discussed, including solar cells utilizing spheres of silicon, large single crystal silicon solar cells, and, longer range varieties of large area silicon solar cells.

2308
Prince, M. B. REPORT ON SILICON SOLAR CELLS. Electron. Indus. & Tele-Tech. 16:60, illus., Mar. 1957

Silicon solar battery and its commercial development.

2309
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. RADIATION DAMAGE STUDY ON SILICON SOLAR ENERGY CONVERTERS, by J. J. Loferski and Paul Rappaport. Final Report. Apr. 15, 1957, n. p. (AD-138 783)

The performance of Hoffman Silicon Solar Cells under simultaneous illumination and irradiation by various ionizing radiations have been observed for the purpose of estimating the useful life of such power sources in the environment of the IGY Earth Satellite. Experiments were conducted in both air and vacuum. The results have been extrapolated with the aid of the best extant theory to yield an estimated minimum life of about ten years for such cells on a satellite. Some observations of voltaic effects induced by protons, electrons, and x-rays are described.

2310
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. RADIATION DAMAGE TO SILICON SOLAR CELLS, by J. A. Baicker, B. W. Faughman, et al. 3 issues, Oct. 1960, Jan., Jly. 1961. (Quart. Repts. 1, 2 and Summary). (Contract NAS5-457)

A study is reported of the effect of protons, electrons, and ultraviolet radiation on silicon solar cells of various efficiencies and construction.

2311
REDS BOAST OF SOLAR BATTERY. Electron. 31:33, Jly. 11, 1958.

Concerns the use of silicon solar cells in Soviet Sputnik III. Each cell is reported to produce 0.5 v.

2312
RUGGEDIZED SOLAR CELLS FOR MISSILES. Electron. Indus. 17:132, Aug. 1958.

Hoffman Type "SS" silicon solar cells are developed to withstand extreme environmental conditions encountered in missile launching and outer space travel.

2313
SILICON CELLS HARVEST SUN'S ENERGY. Elec. Eng. 77:1073, Nov. 1958.

Recent uses of silicon solar cells.

2314
SILICON PHOTOVOLTAIC CELLS. Engr. 212:546, Sept. 29, 1961.

A brief note concerning the development of cells which under ideal load conditions have a high conversion efficiency up to 12-1/2 percent. Two basic manufacturing configurations are being examined--the diffusion of phosphorus and the diffusion of boron.

2315
Space Technology Laboratories, Los Angeles, Calif. ELECTRON BOMBARDMENT OF SILICON SOLAR CELLS, by R. G. Downing. 50 p., Feb. 24, 1960. (Tech. Rept. 60-0000-04057) (Rept. EM 10-5)

The purpose of the experiment described in this report was to define the problem. To accomplish this objective, two approaches were required. First, it was necessary to determine more accurately the sensitivity of solar cells to electron radiation of the type found in space. Secondly, it was necessary to investigate the feasibility of reducing solar cell sensitivity to electron radiation by shielding the solar cell without imparing its photoelectric conversion efficiency. The results of these experiments define the problem and serve as a basis for further quantitative experimental and theoretical study.

2316
Stanford University. Electronics Laboratories, Stanford, Calif. SPECTRAL RESPONSE OF SOLAR CELL STRUCTURES by L. M. Terman. 21 p., illus., Sept. 21, 1959. (Tech. Rept. 1605-1) (Contract Nonr-22531) (AD-226 436)

The purpose of this study was to measure the spectral response of silicon solar cell structures, and to observe how the response varied with the depth of the p-n junction. Spectral response was defined as the relative short-circuit current as a function of the wavelength of incident light for equal energy incident upon the cell at all wavelengths. Cells were made with the junction depths varying from 0.6 to 5.0μ, and having smooth (etched) surfaces and rough (lapped) surfaces. Response curves from these cells are presented. These curves indicate that in order to increase the relative short-wavelength response ($\lambda < 0.75\mu$) the junction should be made closer to the surface, while in order to increase the relative long-wavelength response ($\lambda > 0.75\mu$) the junction must be made comparatively far below the surface. The effect of having a lapped surface on the cell is to reduce the lifetime near the surface, thus reducing the response to short wavelengths of incident light. A simple theoretical model is then presented which appears to adequately describe the mechanism involved in determining the shape of the response curves.

2317
Subashiev, V. K. and Poltinnikov, S. A. DETERMINATION OF THE CARRIER MOBILITY AND DENSITY IN THE SURFACE LAYER OF A SEMICONDUCTOR. Fiz. Tverdogo Tela 2:1169-1177, June 1960.

In Russian. Trans. in Soviet Phys. Solid State 2:1059-1066, figs., Dec. 1960.

Describes a method of determination of the carrier density and mobility in a layer produced by diffusion of an impurity from the surface of a semiconductor. The method is based on measurement of the electrical conductivity and the Hall constant, and it is applied to silicon photocells.

2318
Technical Operations, Inc., Burlington, Mass. RESEARCH DIRECTED TOWARD THE IMPROVEMENT OF THE EFFICIENCY OF SILICON BATTERIES BY UTILIZATION OF UNABSORBED PHOTONS. 15 p., May 1, 1961. (Rept. B61-24) (AFCRL-475) (Contract AF19(604) 7306) (AD-257 495)

The objective was to investigate the possibility of increasing the power output of silicon solar cells by sensitizing the cells to those spectral regions (ultraviolet and infrared) in which they do not respond, and by increasing the absorption and efficiency of the cells in the spectral region in which they do respond. Conclusions are given.

2319
Transitron Electronic Corp., Wakefield, Mass. HIGH EFFICIENCY

SILICON SOLAR CELLS, by Pierre Lamond, A. J. Oszy, et al. 3 issues, Dec. 1959, June, Dec. 1960. (Semiannual Tech. Summary Repts. 1, 2, 3) (Contract DA36-039-sc-85250) (no. 1, AD-232 807, no. 2, AD-245 591)

The objective of this contract is to conduct research investigations leading to the improvement of the practical efficiency of silicon solar cells to 12% or higher. This program also includes studies into methods that will result in high yields and techniques that will permit mass production of these more efficient cells at the lowest possible cost for a 1 x 2 cm cell. An investigation of the factors limiting the efficiency of solar cells has been started. Fabrication of radiation resistant "n-on-p" solar cells is discussed and the process as developed thus far is given.

2320
Turner, R. P. SEMICONDUCTOR DEVICES. 278 p., illus., New York, Holt, Rinehart and Winston, Inc., 1961.

In this survey of semiconductors there is a chapter on photoelectric devices with brief mention of silicon photovoltaic cells, which, used in a connected series, are termed solar batteries, or sun batteries.

2321
U.S. Army Signal Research and Development Laboratory, Ft. Monmouth, N. J. A NEW RADIATION-RESISTANT HIGH-EFFICIENCY SOLAR CELL, by G. Mandelkorn, C. McAfee, et al. 10 p., Oct. 1960. (TR-2162) (AD-247 184) (PB171842)

Details of a phosphorus-diffusion process for fabrication of high-efficiency silicon solar cells are presented. The phosphorus-diffused cells have high efficiencies, and a radiation resistance that is superior to commercial cells by at least an order of magnitude. Data on the electrical characteristics and radiation resistance of the cells are analyzed, and possible application of the new cells to satellite and atomic-powered batteries is considered.

2322
UTILIZING THE SUN'S ENERGY: THE SOLAR BATTERY. Elec. J. 159: 1256-1257, Nov. 1, 1957.

Progress made in investigations into construction and application of silicon solar cells by the British Telecommunication Research, Ltd.

2323
Valdman, H. PREPARATION ET ETUDE DES PILES SOLAIRES AU SILICIUM DE HAUT RENDEMENT. (PREPARATION AND STUDY OF HIGH EFFICIENCY SILICON SOLAR CELLS). Acad. Sci. Paris. Compt. Rend. 252:246-248, Jan. 9, 1961.

In French. Units with an efficiency of 14% can be made by diffusing phosphorus into p-type silicon, and removing the surface layer by etching.

2324
Vavilov, V. S., Vul, B. M., Galkin, G. V., and Fridman, S. A. THE PROBLEM OF OPERATION OF "ATOMIC" CURRENT SOURCES WITH DOUBLE ENERGY CONVERSION. Soviet Phys. Solid State 1:748-748, Nov. 1959.

Trans. of Russian article in Fiz. Tverdogo Tela 1:826-827, May 1959.

It was of interest to obtain preliminary data on the possibility of double conversion (energy of beta-particles $\rightarrow$ light $\rightarrow$ electric energy). For this purpose, experiments were performed with silicon photocells, luminophors with various spectra, and a radiation source in the form of Sr^{90} - Y^{90} with a full strength of 200 mC.

2325
Ziegler, H. K. SOLAR-POWER SOURCES FOR SATELLITE APPLICATIONS. In Berkner, L. V.

ed. Manual of Rockets and Satellites, p. 300-314, New York, Pergamon Press, 1958. (Annals of the International Geophysical Year, vl. VI)

Progress in the field of solar-power sources for satellites since 1956 is reviewed. Investigations on silicon solar cells, improving their efficiency and determining their durability to high intensity radiation; energy storage devices; silicon-type solar power supplies designed and produced by the US Army Signal Engineering Laboratories for the Vanguard satellite program are mentioned.

3. Compound Semiconductors

2326
Armour Research Foundation, Chicago, Ill. INVESTIGATION OF SINGLE ENERGY GAP SOLAR CELL MATERIAL, by R. J. Robinson, 42 p., illus., Dec. 31, 1955. (Periodic Rept. 1) (Rept. 1155-1) (Contract DA36-039-sc-85247) (AD-234 689)

The purpose of this program is to develop, if possible, a single gap solar cell material which lends the possibility of lower production cost, increased practical efficiency and better high temperature characteristics than can be expected from silicon. The material chosen for investigation is cadmium telluride. Cadmium telluride is comparatively a new material in semiconductor technology, and this period report is primarily concerned with crystal growth aspects, consistent with the early state of the art development. The properties of cadmium telluride are being measured as a two part study. The first part is concerned with a new tool utilizing fluctuation phenomena which is being used to better understand the junction characteristics of a solar cell; the method helps in understanding recombination-generation currents as well as diffusion currents. A correlation study is now underway. A method of depositing thick, stoichiometric films of cadmium telluride is discussed and the status of this phase of the program is described.

2327
Armour Research Foundation, Chicago, Ill. INVESTIGATION OF SINGLE ENERGY GAP SOLAR CELL MATERIAL. 26 p., Dec. 31, 1960. (Rept. 1175-3) (Tech. Summary Rept 1) (Periodic Rept 3) (Contract DA36-039-sc-87381) (AD-251 950)

Work has been primarily concerned with: (1) preliminary electrical and optical evaluation of the zone refined CdTe; (2) assembling a system for alloying and diffusion studies; and (3) fabrication of a few photovoltaic cells from the zone refined material.

This report also includes Apparatus for zone melting in a controlled atmosphere, by Sherman Susman and George Yamate, 11 p., illus.

2328
Fink, C. G. and Alpern, D. K. THE ENGINEERING DEVELOPMENT OF PHOTOVOLTAIC CELLS. Electrochem. Soc. Trans. 58:275-298, 1930.

Cuprous oxide cells produce about 15 milliamp with sunshine, but the cells soon polarize. Maximum sensitivity at 0.46 micron.

2329
Galavaniv, V. V. and Erokhina, N. A. PREPARATION OF A PHOTOVOLTAIC CELL FROM InSb WITH AN ALLOYED n-p JUNCTION. Fiz Tverdogo Tela 1:1198-1200, 1959.

In Russian. Trans. in Soviet Phys. Solid State 1:1096-1098, 1959.

InSb is photosensitive at long wavelengths and consequently it is suitable for preparation of infrared detectors. Such detectors were developed using the photoelectromagnetic effects in InSb. Some workers used InSb as a photoconductive cell. Attempts to prepare a photovoltaic cell with a n-p junction, the latter being

produced during growth of monocrystals, having been reported. Such n-p junctions were quite sensitive to light in spite of the absence of the rectifying action of the liquid-nitrogen temperature. The present paper discusses the possibility of preparation of an InSb photovoltaic cell with an alloyed n-p junction.

2330
Greenland, K. M. PHOTOELECTRIC CELLS. Control 2:90-96, Feb. 1959.

Photoemissive and photovoltaic cells are briefly described in an article intended to serve as a concise guide to advances in the field of semiconductor photocells.

2331
Harshaw Chemical Co., Cleveland, Ohio. A CADMIUM SULFIDE SOLAR GENERATOR, by D. A. Hammond, F. A. Shirland, and R. J. Baughman. 128 p., illus., Dec. 1957. (WADC TR 57-770) (AD-151 036) (PB 151 276)

The efficiency of CdS photovoltaic cells was increased to a range of 3 to 5% from an average of 0.4% by improved doping, growth, cleaning, and electroding techniques. The method for making CdS cells is outlined. Two small solar generators were assembled from these cells for demonstration and testing purposes. Each of these gave about 50 milliwatts of power at about 6-7 v when illuminated by direct sunlight.

2332
Harshaw Chemical Co. Solid State Research Dept., Cleveland, Ohio. RESEARCH ON A COMPOSITE ENERGY GAP PHOTOVOLTAIC CELL. 2 issues, June, Sept. 1961. (Quart. Prog. Repts. 8, 9) (Contract AF33(616)-6548)

Two avenues of attempts to fabricate a composite photovoltaic cell have been followed. The first was to evaporate selected materials onto cadmium sulphide, and by a subsequent heat treatment, attempt to obtain an intimate bond. The second was to react one element, in the case described, selenium, with cadmium sulphide in such a way as to form cadmium selenide in contact with the sulphide.

A distinction between photorectification and the photovoltaic response has been recognized, and a possible model suggested.

2333
Harshaw Chemical Co. Solid State Research Dept., Cleveland, Ohio. RESEARCH ON SOLAR-ELECTRICAL ENERGY CONVERSION EMPLOYING PHOTOVOLTAIC PROPERTIES OF SEMICONDUCTORS CADMIUM SULFIDE. 2 issues, Apr. 28, Jly. 20, 1961. (Quart. Prog. Repts. 3, 4) (Contract AF33(616)7528)

Research on the photovoltaic properties of semiconductive CdS, and development of reproducible lightweight CdS film photovoltaic cells were continued in this report period.

2334
IMPROVED SOLAR CELLS DEVELOPED. Aviat. Wk. & Space Tech. 74:83, May 29, 1961.

"Gallium arsenide solar cells, which have a higher theoretical conversion efficiency than present silicon cells, have achieved efficiencies up to 14.7% in laboratory samples, R. W. Runnels of the Aeronautical Systems Division's Electronic Technology Laboratory reported at Naecon. Samples were in 3-cm square sizes. Another promising solar cell development is the use of new polycrystalline materials, such as cadmium telluride, which can be fabricated in large structures at relatively low cost, Runnels said. New ternary compounds, such as aluminum antimonide, which are most responsive to solar energy in the 0.2 to 2.0 micron region where the sun's energy is strongest, also are under investigation." Entire item quoted.

2335
Jenny, D. A., Loferski, J. J. and Rappaport, Paul. PHOTOVOLTAIC EFFECT IN GaAs DIFFUSION JUNCTIONS. Am. Phys. Soc. Bull. 1:111, 1956.

Abstract only of paper presented at 1956 March meeting of the American Physical Society, Pittsburgh, March 15-17, 1956. "P-n junctions have been made on n-type GaAs by diffusing Zn, Cd, or Hg from the vapor phase. Decomposition of GaAs and formation of secondary compounds such as the arsenides of the diffusing element complicate the process. We have estimated that the upper limit for the diffusion coefficient for these acceptors is 10^{-12} cm^2 sec^{-1} at 800°C. According to the theory of solar energy conversion, [1] p-n junctions made on GaAs, which has a band gap of 1.35 ev, should be nearer the highest obtainable efficiency than junctions on Si. Furthermore, since the electron mobility is at least four times higher than in Si, conduction losses are reduced in actual GaAs photovoltaic cells, and the attainable efficiency should therefore approach the theoretical efficiency more closely. Measured efficiencies are still well below theory; for sunlight, as high as 6.5% has been obtained at quantum yields of about 0.4. The spectral response of the photovoltaic current shows a cutoff near 1.35 ev in agreement with other measurements of the band gap." Entire item quoted.

2336
Jenny, D. A., Loferski, J. J. and Rappaport, P. PHOTOVOLTAIC EFFECT IN GaAs p-n JUNCTIONS AND SOLAR ENERGY CONVERSION. Phys. Rev. 101:1208-1209, Feb. 1, 1956.

Some preliminary experiments are described on GaAs p-n junctions used as solar energy converters and their operation is compared to that predicted by the theory of the photovoltaic effect.

2337
LIGHT MAGIC WITH SEMICONDUCTOR DEVICES. Eng. 190:239, Aug. 19, 1960.

Possibilities for increasing efficiency and reducing cost of solar cells, which convert sunlight directly into electricity. It is suggested that material other than silicon must be found which has better response in violet region of light.

2338
Moss, H. I. LARGE-AREA THIN-FILM PHOTOVOLTAIC CELLS. RCA Rev. 22:29-37, Mar. 1961.

Progress has been made with vacuum deposition of CdS on to heated transparent conducting surfaces. Solar conversion efficiencies of 1% are reported.

2339
Moss, T. S. THE POTENTIALITIES OF SILICON AND GALLIUM ARSENIDE SOLAR BATTERIES. Solid State Electron. 2:222-231, May 1961.

The theory of the spectral response of a p-n junction solar battery unit is given, and detailed comparisons are made of the expected performance of silicon and gallium arsenide units.

2340
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. INVESTIGATION OF HIGH-TEMPERATURE PHOTOVOLTAIC SOLAR ENERGY CONVERTER, by J. J. Wysocki, J. J. Loferski, and Paul Rappaport. 5 issues, 1958, 1959, 1960. (Triannual Prog. Repts. 1, 2, 3, 4 and Final Progress Rept.) (Contract DA36-039-sc-78184) (AD-213 949, AD-220 128, AD-228 009, AD-230 412, and AD-252 010)

Titles varies. Repts. 4, 5 and Final are High Temperature, Improved Efficiency, Photovoltaic Solar Energy Converter.

Attempts are described to achieve higher-efficiency GaAs solar cells by fabrication improvements.

2341
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. INVESTIGATION OF MATERIALS FOR PHOTOVOLTAIC SOLAR ENERGY CONVERTERS, by J. J. Loferski, et al. 6 issues, 1955, 1956, 1957. (Interim Repts. 1 through 5, and Final) (Contract DA36-039-sc-64643) (AD-80 111, AD-91 576, AD-111 732, AD-126 093, AD-134 060, AD-156 240)

A theoretical analysis indicates that a semiconductor with an energy gap about 1.5 ev should yield the most efficient solar energy converter based on the photovoltaic principle. GaAs, InP, CdTe with energy gaps of 1.35, 1.25 and 1.45 ev, respectively, were investigated to verify this. Efficiencies as high as 6.5% were obtained with better results to be expected as crystal perfection is improved. Results on compound semiconductor technology are reported, including alloy and diffusion junctions techniques, ohmic contacts, etchants, etc. A new high-voltage photovoltaic effect capable of producing as high as 1500 volts in sunlight was discovered using evaporated CdTe films. The devices, are, at present, of high impedance and low efficiency. The technique for making such films and their physical measurements are presented. CdTe single-crystal technology is also presented in detail.

2342
Radio Corp. of America, David Sarnoff Research Laboratories, Princeton, N. J. SEMICONDUCTOR PHOTOVOLTAIAC CONVERSION, by J. J. Wysocki, B. Goldstein, R. Novak, and J. Scott-Monck (Triannual Report) 41 p., illus., Mar. 31, 1961. (Contract DA36-039-sc-87417) (AD-258 131)

The solution-growth technique for fabricating GaAs solar cells and its limitations are discussed. The best cell made by this method had an efficiency of 2%. Preliminary work on heterojunctions and cells made from GaAs alloys is reported. The diffusion of P in GaAs is slowed down by the presence of Zn (5×10^{19} atoms/cc) by a factor of 2 at 1120°. No GaP is observed even for P surface concentrations of $10^{22}/cm^3$. Johnson's Data for the solar irradiance has been converted to yield the number of available photons outside the earth's atmosphere. The total number of photons is $6.4 \times 10^{17}/cm^2/sec$, and their average energy is 1.36 ev. The critical flux required to reduce the efficiency of GaAs solar cells by 25% was $1.8\text{-}3.5 \times 10^{15}$ electrons/cm^2 at bombardment energies of 800 kev. The fabrication of oxygen-free Si n on p cells is discussed. Critical fluxes for three such cells varied from 1.5×10^{15} to 2×10^{16} electrons/cm^2 at 800 kev. Absolute spectral responses of these cells indicate damage in the base and possibly to the diffused skin. The study of bulk conductivity changes as a result of electron bombardment indicate some change in an n-type Si blank with 2.7Ω-cm resistivity for electron energies as low as 185 kev.

2343
Tauc, J. and Abraham, A. THE PHOTOELECTRIC PROPERTIES OF INDIUM ANTIMONIDE. Czechoslov. J. Phys. 4:478-485, 1954.

A change of resistance or the formation of a voltage in mono- or polycrystalline samples of InSb due to illumination has been observed, the magnitude of which increase with decreasing temperature. It is demonstrated that this is a photoconductive effect and a photovoltaic effect. These phenomena are caused by the transition of electrons from the valence band to the conduction band under the influence of photons.

2344
U.S. Air Force. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. A CADMIUM SULFIDE SOLAR GENERATOR, by D. A. Hammond,

F. A. Shirland, and R. J. Baughman. 128 p., illus., Dec. 1957. (Tech. Rept. 57-770) (AD-151 036) (PB 151 276)

The efficiency of the CdS photovoltaic cells was increased to a range of 3 to 5 per cent from an average of 0.4 per cent by improved doping, growth, cleaning, and electroding techniques. The method for making CdS cells is outlined. Two small solar generators were assembled from these cells for demonstrating and testing purposes. Each of these gave about 50 mw of power at about 6-7 v when illuminated by direct sunlight.

2345

U.S. Air Force. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. RESEARCH ON METHODS OF TREATING CADMIUM SULFIDE ELEMENTS, by Allan Carlson, Warren Deshotels, J. M. Jost, and L. R. Shiozawa. 52 p., Nov. 1957. (Tech. Rept. 57-749) (AD-151 024) (PB 131847)

Part of a program for the development of a cadmium sulfide single crystal solar battery. Emphasis was placed on a fundamental study of photovoltaic electrodes formed on cadmium sulfide crystals by copper compounds. It was found that the behavior of such junctions as circuit elements was in agreement with published theory. The cells had photoelectric energy conversion efficiencies in sunlight ranking between that of selenium and silicon solar batteries. A number of other ohmic and non-ohmic electrodes on cadmium sulfide crystals were also prepared and studied.

2346

Vadokov, Y. A., Lomakina, G. A., Naumov, G. P., and Maslakovets, Y. P. A p-n JUNCTION PHOTOCELL MADE OF CADMIUM TELLURIDE. Soviet Phys. Solid State 2:1-10, 1960.

Trans. of Russian article in Fiz. Tverdogo Tela 2:3-7, Jan. 1960.

Voltage characteristics are similar to those of silicon photocells. The efficiency of conversion of solar energy into electrical power cadmium telluride photocells is at present about 4%, and therefore, these photocells can be used in solar batteries.

2347

Wolff, G., Keck, P. H., and Broder, J. D. PREPARATION AND PROPERTIES OF III-V COMPOUNDS. Phys. Rev. 94:753, 1954.

Considerable interest has been shown in the phosphides, arsenides, and antimonides of Ga, In, and Al. A technique was developed for growing single crystals from solution. Single-crystal plates of GaP, GaAs, GaSb, InP, InAs, InSb, and AlSb were obtained. Some of the crystals are up to 12 mm long and 1.5 mm thick. In all cases (111), ($1\bar{1}1$), (001) planes appeared. The twinning plane (111) and the cleavage plane (011) and occasionally ($1\bar{1}1$), were observed in the crystals. Differences between (111) and ($1\bar{1}1$) were found for GaAs, InP, InAs, and AlSb. Thermoelectric tests indicate n-type conduction more frequently than p-type. Some of these compounds also show a strong effect.

2348

Wysocki, J. J., Loferski, J. J. and Rappaport, Paul. PHOTOVOLTAIC CONVERSION. 4. RESEARCH ON PHOTOVOLTAIC CONVERTERS. In Power Sources Conference. Proceedings, 14th, 1960, p. 32-36, Red Bank, N. J., PSC Publications Committee, 1960.

A summary of research at RCA Laboratories indicates that major effort has been on GaAs solar cells, although some work has been done on other materials such as GaP. Other solar energy converters have been considered; in particular, the PEM (Photo-ElectroMagnetic) energy converter.

4. Devices

2349
ADVANCEMENT IN SOLAR ENERGY USE DEMONSTRATED. Elec. Eng. 75:957-958, illus., Oct. 1956.

Concerns solar-powered devices unveiled by Hoffman Electronic Corporation and International Rectifier.

2350
AIR FORCE OUTLINES BROAD EFFORT IN SOLAR POWER RESEARCH. Missiles & Rockets 6:36-38, June 27, 1960.

Report on contract work for U.S. Air Force by 30 contractors on solar power conversion devices, including energy storage in Type F Ni-Cd batteries and fuel cells.

2351
Alexander, G. E. and Eichholz, G. G. RECORDING SYSTEM FOR GALVANOMETER BEAM DEFLECTIONS: LIGHT-SENSITIVE DETECTOR USED IN A SILICON SOLAR CELL. Electron. Eng. 33:38-39, diags., Jan. 1961.

The equipment described was designed to observe and record the passage of a focused light beam at a series of points on a galvanometer scale to an accuracy of 1 mm. The light-sensitive detector used is a silicon solar cell and the equipment uses transistors throughout.

2352
Cherry, W. R. MILITARY CONSIDERATIONS FOR A PHOTOVOLTAIC ENERGY CONVERTER. In Conference on the Use of Solar Energy--The Scientific Basis, Tucson, 1955. Transactions. vl. 5, p. 127-132, illus., Tucson, University of Arizona, 1958.

Utilization of solar energy for U.S. Signal Corps equipment is likely only where non-continuous operation is tolerable, in operations above the earth's atmosphere, or in conjunction with electrical storage devices. First research objective at work underway for the Signal Corps at the RCA Lab., Princeton, N. J., is to establish the most suitable material for a given set of solar radiation conditions.

2353
Cherry, W. R. PHOTOVOLTAIC CONVERSION. 5. ADVANCED PHOTOVOLTAIC DEVICES. In Power Sources Conference. Proceedings, 14th, 1960, p. 37-42, Red Bank, N. J., PSC Publications Committee, 1960.

New research programs for advanced solar converters are discussed.

2354
Conference on the Use of Solar Energy. The Scientific Basis, Tucson, 1955. TRANSACTIONS. 5 vls. in 6, Tucson, University of Arizona, 1958.

For analysis of contents see entries for: Chapin, D. M., Cherry, W.R., Cummerow, R. L., Daniels, Farrington, Gier, J. T., Jackson, E. E., Marcus, R. J., O'Day, M., Sancier, K. M., and Telkes, Maria.

2355
THE DIRECT TRANSFORMATION OF SOLAR ENERGY INTO ELECTRIC POWER. J. Four. Elec. 66:31-32, 1961.

In French. The principle of the solar pile erected at Toulon by the Cie. Générale de Télégraphie Sans-Fil is described, and its method of operation and the results obtained are presented. (Met. Abs. 28:941, 1961)

2356
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume V, DIRECT SOLAR CONVERSION, by W. Evans and W. R. Menetrey. 207 p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. V) (Contract AF33(616)6971) (AD-257 788) (PB 171 862)

The performance characteristics of the photovoltaic converter when used

to convert solar radiation directly to electrical energy is described in detail. Empirical and analytical relationships are derived which present expected efficiencies of conversion as a function of temperature, solar insolance, and other factors. A discussion is also included describing the state of the art and practical and theoretical limitations of the photoemissive generator. It does not appear at present that the photoemissive generator offers competition to the photovoltaic cell.

2357
Elliott, J. F. DESIGN CONSIDERATION FOR A HIGH RELIABILITY PHOTOVOLTAIC SOLAR ENERGY CONVERTER. Solar En. 3:34-35, figs., Apr. 1959.

Solar radiation data have been examined to determine the storage requirements for a photovoltaic solar energy conversion system having a high reliability. It has been found that a low failure rate can be obtained with one and one-half days' storage if the demand power rate is set at about one-half the winter's average daily production rate.

2358
Feaster, G. R. THERMIONIC DIODES AS ENERGY CONVERTERS: AN ADDENDUM. J. Electron. & Contr. 5:142-145, diags., 1958.

An analysis is given of the operation of a space-charge neutralized, thermionic diode energy converter having an anode work function smaller than the cathode work function. It is shown that, in contrast to the more conventional diode, output potentials of the order of one volt are available when the diode is loaded for maximum power output.

2359
General Electric Co. Semiconductor Products Dept., Syracuse, N. Y. INVESTIGATIONS OF LARGE AREA PHOTOVOLTAIC SOLAR ENERGY CONVERTERS, by J. F. Elliott. 19 p., Dec. 31, 1960. (Tech. Summary Rept. 2) (Contract DA36-039-sc-85286) (AD-251 653)

Efforts to further improve solar cells made from mechanically deformed silicon have not been successful. (This portion of the large area solar cell program has been discontinued.)

A new deposition apparatus has been built and placed in operation for preparing thin films of silicon by the reduction of $SiCl_4$. Single crystal films have been prepared with resistivities of about 5 ohm-cm over areas of about 3/4 square inch. These single crystal films are to be used as a basis for understanding the nature of the polycrystalline film.

Preliminary attempts to prepare p-type films using BCl_3 as a doping agent have resulted in single crystal p-type films.

2360
Hoffman Electronics Corp., Santa Barbara, Calif. COATINGS FOR SOLAR CELLS, Final Report, by R. M. Witucki and A. E. Lewis. 86 p., illus., Feb. 28, 1961. (AD-258 660)

It was concluded that single thin film coatings alone, of 1 micron or less in thickness, can not provide either adequate emissivity or high selective reflectivity of the wavelengths required and still show high transmission from 0.45 to 1.1 micron. A high emissivity was found to be the most important single method of rejecting energy in space. Therefore attention was directed primarily toward achieving maximum emissivity. Emissivities of the order of 0.9 can only be obtained using coatings of several mils thickness. Silicone coatings were found to be very simple and inexpensive to apply, and within the accuracy of available data to show a predicted performance in space equivalent to the presently used ultra-violet reflecting coated

cover glasses. Numerous laboratory tests of limited time duration have shown the selected silicone coating to be stable to the expected environmental conditions during storage as well as in space.

2361
International Technical Conference on Lighthouses and Other Aids to Navigation, 6th. ABSTRACTS OF REPORTS. 78 p., Washington, D.C., U.S. Coast Guard, Sept. 26, 1960.

Abstracts on pages 18-21 are of interest, the titles being: A Power System for Aids to Navigation on Buoys (United States); Possible Method of the Use of Solar Energy (United Kingdom); and Unattended Lighthouse Using Solar Batteries as Power Source (Japan).

2362
Isaacs, G. W. SOLAR-POWERED ELECTRIC FENCE CHARGER. Electron. 30:188-192, Dec. 1957.

Electric fence charger powered by silicon solar cells is being tested at the Purdue University Agricultural Experimental Station.

2363
Land, T., Barber, R., and Burley, B. W. SOLAR CELLS IMPROVE PYROMETER PRECISION. Eng. 192:362-363, illus., Sept. 15, 1961.

Use has been found for the silicon solar cell in connection with industrial radiation pyrometry. It improves the sensitivity, the response-time, and the accuracy.

2364
Mann, A. E. PHOTOVOLTAIC CONVERSION. 3. SPECTRALLY SELECTIVE OPTICAL COATINGS. In Power Sources Conference. Proceedings, 14th, 1960, p. 28-32, Red Bank, N. J., PSC Publications Committee, 1960.

Purposes of the coatings are discussed. They are: (1) to reduce operating temperature; (2) increase efficiency; (3) provide protection against mechanical damage, surface contamination, micrometeorite erosion and beta radiation.

2365
Mitchell, W. K. SUN-POWERED CAR. Popular Mech. 107:233, illus., Feb. 1957.

Model car solar-powered by means of 12 selenium cells connected to an electric motor.

2366
MORE USES FOR SOLAR CELLS. Electron. 31:20-21, illus., Aug. 8, 1958.

Recent applications of silicon cells.

2367
National Academy of Sciences. National Research Council, Washington, D.C. SOLAR BATTERIES, by V. S. Vavilov, and A. P. Landsman. 9 p., Aug. 9, 1958. (Rept. B.5)

Trans. of paper presented at the Rocket and Satellite Symposium during the Fifth Reunion of the Comité Special Annee Geophysique Internationale held in Moscow July 30-Aug. 9, 1958.

Means for further increasing the effectiveness and securing the reliable operation of solar batteries are discussed. Data on the operation of solar batteries in the third Soviet artificial satellite are cited.

2368
Neal, H. R. WILL ELECTRIC CARS COME BACK? ADVANCES IN SOLAR ENERGY CONVERSION REVIVES INTEREST. Iron Age 180:32-35, illus., Dec. 26, 1957.

Possibility of powering automobiles with silicon solar cells.

2369
Nisbet, T. R. DESIGNING SOLAR CELL POWER SUPPLIES. Electron. Equip. Eng. 8:75-78, Feb. 1960.

Combination of solar cell arrays and battery requires consideration

of the inherent diode formed by the p-n junction of the cell, intensity of illumination, occurrence of darkness, isolation diodes, and environment.

2370
O'Day, M. THE TECHNICAL AND ECONOMIC LIMITATIONS OF LOW-VOLTAGE GENERATORS FOR THE PRODUCTION OF LARGE AMOUNTS OF ELECTRIC POWER. In Conference on the Use of Solar Energy: The Scientific Basis, Tucson, 1955. Transactions vl. 5, p. 31-35, Tucson, University of Arizona, 1958.

Direct conversion of solar heat into electrical power has the disadvantage of the low voltage of the generating element. Practical problems to be solved have more to do with the cost of materials necessitated by low resistance considerations than with efficiencies.

2371
Pearson, G. L. APPLICATIONS OF PHOTOVOLTAIC CELLS IN COMMUNICATIONS. 11 p., illus., New York, United Nations, Apr. 14, 1961. (E/CONF. 35/S/40)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

Applications of solar batteries in terrestrial telephone systems and in space vehicles are described. In addition, new configurations of light sensitive p-n-p silicon diodes are described which promise to be useful in frequency modulated communication systems.

2372
Rappaport, Paul and Moss, H. I. LOW-COST PHOTOVOLTAIC CONVERSION OF SOLAR ENERGY. 10 p., illus., New York, United Nations, May 20, 1961. (E/CONF. 35/S/106)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961

Present day solar cells are much too expensive to provide electrical power for everyday terrestrial application. The major reason for this is the need to make single crystals. Solar cells that are made by a deposition technique from a suitable raw material would be inherently inexpensive. A cost of $1 to $10 per square foot of a 10% efficient solar cell would probably bring the cost into the range of economic feasibility for home use. A practical and inexpensive cadmium sulfide solar cell that at 3.5% is efficient has been achieved. Such cells may be perfected to yield 6%, however, with further research other materials such as silicon may yield an inexpensive film-type cell with efficiencies approaching 10%.

2373
Ravich, L. E. THIN FILM PHOTOVOLTAIC DEVICES FOR SOLAR ENERGY CONVERSION. 36 p., illus., New York, United Nations, April 25, 1961. (E/CONF. 35/S/56)

Theoretical and practical limitations of presently available solar cells are briefly reviewed and a current research program (at Itek Corp.) is described whose objectives are to provide large area, low cost photovoltaic layers possessing the reliability and simplicity of fabrication and operation required for solar energy conversion devices designed for operation in less developed areas.

2374
Sancier, K. M. PHOTO-GALVANIC CELLS. In Conference on the Use of Solar Energy: The Scientific Basis, 14 p., Tucson, 1955. Transaction, vl. 5, p. 43-56, Tucson University of Arizona, 1958.

Requirements of photo-galvanic cells which will make possible the construction of a practical cyclic solar battery. Properties and mechanism of operation of four types of such cells are tabulated. To reverse the photochemical reaction by the galvanic action of the battery, an oxygen-graphite counter-half-cell consuming atmospheric oxygen only is suggested. Extensive bibliography and abstracts of recent references on photo-galvanic cells are included.

2375
Smits, F. M., Smith, K. D., and Brown, W. L. SOLAR CELLS FOR COMMUNICATION SATELLITES IN THE VAN ALLEN BELT. Brit. Inst. Radio Engrs. J. 22:161-169, figs., Aug. 1961.

This paper discusses in detail the considerations entering in the design of a solar plant for long life satellites exposed to the radiation environment of the Van Allen belt. In Section 2 data on Van Allen radiation are interpreted, Section 3 reviews solar cell theory, Section 4 described the design of the solar cell developed for satellite application at Bell Telephone Laboratories, and in Section 5 the bombardment studies on these solar cells are given. These studies, in combination with the radiation environment assumptions given in Section 2, permit prediction of the solar cell performance in time as a function of exposure to Van Allen radiation.

2376
SOLAR BATTERIES FOR SATELLITE. Army-Navy-Air Force Register 78:6, June 29, 1957.

Refers to successful operational testing of solar cells attached to the skin of an Aerobee-Hi rocket.

2377
SOLAR BATTERY: BELL LAB'S UNIT CONVERTS LIGHT DIRECTLY TO ELECTRICITY. Iron Age 173:51, Apr. 29, 1954.

This is a brief announcement of a new device.

2378
SOLAR-CELL SENSING USED IN NOVEL ACCELEROMETER. Electron. Design 9:6-7, Apr. 26, 1961.

An accelerometer has been developed in which movement of a pendulum with acceleration is detected by using a light beam and two identical solar cells. Acceleration can be measured to 1 part in 10^4 and level can be detected to within 10^{-1} second of arc.

2379
SOLAR CELLS FOR MARINE BUOY LIGHTING. Electron. Eng. 33:425, illus., Jly. 1961.

The use of silicon solar cells for providing power for recharging batteries for marine buoy lighting is being investigated by the Corporation of Trinity House, the authority responsible for the maintenance of lighthouses, lightships, and marine buoys around the coasts of England and Wales.

A large experimental installation containing 400 solar cells, wired in series parallel has been made, the power derived from this bank being used to charge ten NIFE storage cells. This is intended for use on navigational lights situated in river estuaries, and it is hoped that investigations carried out on this installation will reveal whether it can be used successfully as the main source of power for operating a light without having to rely on a shore-based electrical installation.

2380
SOLAR CONVERTERS POWER SATELLITES. Electron. Indus. 17:14, May 1958.

Use of Hoffman solar cells in Vanguard satellites.

2381
SOLAR ENERGY IN THE SPACE AGE. The Sun at Work 3:3-4, Dec. 1958.

The work of several agencies is reviewed to indicate the interest in increasing the amount of power furnished by solar cells.

2382
Strand, H. P. BUILDING A WORKING SOLAR BATTERY AND MOTOR. Part I. THE SOLAR BATTERY. Part II. THE SOLAR MOTOR. Sci. and Mech. p. 167-170, June; Jly., 1956.

Detailed instructions for building a simple solar battery, using self-generating photoelectric cells, and a small motor which will run from the battery.

2383
Technology Instrument Corp., Action, Mass. PHOTOVOLTAIC SOLAR ASPECT SYSTEM. 5 p., n. d.

Four small solar cells are utilized in the sensing element.

2384
Transitron Electronic Corp., Wakefield, Mass. RESEARCH ON EFFICIENT PHOTOVOLTAIC SOLAR ENERGY CONVERTERS. Final Report, by B. Dale. 63 p., June 23, 1960. (AFCRL-Tech. Rept. 60-379) (Contract AF19(604)5585) (AD-251 930) (PB 171 270)

This report covers various phases of the subject with recommendations as to which material and technique offers the most promise for the near future. The most promising system appears to be the use of two cells matched to different parts of the sun's spectrum in conjunction with a dichroic mirror to direct the appropriate part of the spectrum to each cell.

2385
Trivich, D. PHOTOVOLTAIC CELLS AND THEIR POSSIBLE USE AS POWER CONVERTERS FOR SOLAR ENERGY. Ohio J. Sci. 53:300 314, 1953.

Various types of photovoltaic cells which may be used to convert solar energy into electrical energy are discussed.

2386
U.S. Coast Guard, Washington, D.C. TESTS OF A SOLAR POWERED AID TO NAVIGATION. 14 p., illus., June 14, 1961. (AD-259 675)

This report describes the operational tests of a solar-powered battery charger for a U.S. Coast Guard aid to navigation. The system tested consisted of four watertight modules of 80 type 2-A Hoffman Cells designed for 6-volt application. The four modules were connected in a series-parallel array to sustain a 12-volt 1.35 ampere lamp load flashing on a one-tenth duty cycle. The tests demonstrated the ability of the system to carry typical aids to navigation loads through two successive winters at the Los Angeles, California, test site.

5. Systems

2387
Baum, V. A. RESEARCH ON THE USE OF SOLAR ENERGY MADE IN THE SOVIET UNION. Natl. Acad. Sci. Proc. 47: 1262-1270, Aug. 1961.

Projects undertaken at the Helio Laboratory of the Power Institute of the Soviet Academy of Sciences are reviewed. They have to do with transformation of solar radiation into mechanical or electrical energy by means of the ordinary steam system, solar thermoelectric generators, and by solar photoelectric batteries.

2388
California Institute of Technology. Jet Propulsion Laboratory, Pasadena, Calif. SPACE PROGRAMS SUMMARY No. 37-9. Volume I. 100p., June 1, 1961. (Contract NASw-6)

The Rangers RA-1 and 2 are described. The RA-1 power system derives its power from two solar panels with a total area of 20 ft^2 and a primary battery which provides power during those intervals when the solar panels are not illuminated. The raw power from the solar panels and battery is fed to a booster regulator which provides a 1% regulated dc voltage to feed several converters and inverters which, in turn, supply individual users.

2389
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume III, DYNAMIC THERMAL CONVERTERS, by C. W. Stephens, R. Spies, and W. R. Menetrey. 214 p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. III) (Contract AF33(616)-6791) (AD-256 701)

Discusses the Stirling engine and the Rankine cycle turbines with equations describing performance, also

electrostatic and electromagnetic generators which are coupled with thermoconverters.

2390
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume IV, STATIC THERMAL CONVERTERS, by J. Blair and J. D. Burns. 210 p., Sept. 1960. (WADD Te a. Rept. 60-699, vl. IV) (Contract AF33(616)6791) (AD-256 702)

2391
Escoffery, C. A. PHOTOVOLTAIC CONVERSION OF SOLAR ENERGY. In American Power Conference, Proceedings March 29-31, 1960, Chicago, Ill., vl. 22, p. 470-476, Chicago, Illinois Institute of Technology Press, 1960.

Technical and economic aspects of the utilization of solar energy by photovoltaic conversion are discussed.

Also in Semiconductor Prod.3: 35-38, Dec. 1960.

2392
Gaumer, R. E. MATERIALS FOR SOLAR-ENERGY SYSTEMS. Space/Aero. 36:60-65, illus., Oct. 1961.

The basic thermophysical parameters that determine a material's usefulness for solar-energy systems and for the external heat protection of space-craft are solar absorptance, infrared emittance, and reflectance. This survey shows how these parameters are determined, how they apply to the different elements of power conversion and temperature control systems, and compares available material on this basis. Methods of determining the thermophysical parameters and environmental and structural factors are also discussed.

2393
Hoffman Laboratories, Inc., Los Angeles, Calif. DESIGN STUDY OF A STATIC SOLAR ELECTRICAL POWER SYSTEM, by L. A Ule and J. S. Smatko. 90 p. illus., Mar. 1960. (WADC Tech. Note 59-380) (Contract AF33(616)6617) (AD-237 181)

A design study of the parameters affecting the design of a static solar electrical power system for earth-orbiting satellites is presented. This power system is to be capable of reliable operation over a period of one year. Two basic orientation systems were studied in detail. One involves mounting of the solar cell converter panels at the top of the vehicle and the other involves a side mounted panel. The side mounted panel was selected since it produces the smaller disturbance to the vehicle. A battery test program was outlined to determine the permissible depth of discharge of nickel-cadmium batteries for a life-time of one year at the charge-discharge rates called for in this system. Studies were made on converter panels which have the highest efficiency in a space environment. Glass covers and coatings of cells and panels are considered. Other studies were presented including the optimum design of the voltage regulating system, the design of various types of brushless DC motors, the investigation of liquid metal bearings and slip rings, and a system error analysis.

2394
Johns Hopkins University. Applied Physics Laboratory, Silver Spring, Md. DESIGN OF THE TRANSIT SATELLITE ELECTRONICS SYSTEM, by J. W. Hamblen and J. B. Oakes. 36 p., Sept. 1960. (Rept. TG-394) (Contract Nord-7386)

A description of the power supply system is given on p. 31-34. The Transit 2-A power supply represents a considerable advancement over that of the 1-B. It represents the first completely solar powered Transit. A single nickel-cadmium battery, consisting of twelve "F" size cells, is employed. This battery is recharged by solar cells.

2395
Johns Hopkins University. Applied Physics Laboratory, Silver Spring,

Md. DEVELOPMENT OF THE POWER SUPPLY OF THE TRANSIT SATELLITE, by W. C. Scott. 47 p., Dec. 1960. (Rept. CM-986) (Contract Nord-7386) (AD-252 681L)

This CM covers the development of the power system and deals with the silicon photovoltaic converters, the rechargeable nickel-cadmium batteries, the zinc-silver oxide batteries used in an early version, and the static conversion equipment.

2396
Joquel, A. L., II. SOLAR POWER AND THE ARTIFICIAL SATELLITE. The Sun at Work 2:3-4, 15, June 1957.

The role of solar energy in Project Vanguard is briefly mentioned.

2397
Karcher, R. W. SOLAR CELL POWER SYSTEM FOR ADVENT. In Snyder, N. W. ed. Space Power Systems, p. 11-18, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4).

Orbit imposed conditions, mechanical design considerations, and cell connection for the Advent Communication Satellite are discussed.

2398
Lemus, F. RELIABILITY EVALUATION OF A SATELLITE POWER-SUPPLY SYSTEM. Mil. Sys. Design 5:8-11, figs., Mar/Apr. 1961.

Evaluation of the reliability of a moderately complex system in terms of average-time-to-failure and the probability of its specified operation for a specified minimum time is discussed for a sun-powered satellite power supply system. The method is applicable to other complex engineering systems.

2399
McCubbin, J. G. and Goldberg, H. B. BEACON TRANSMITTERS AND POWER SUPPLY FOR ECHO I. RCA Rev. 22:147-161, figs., Mar. 1961.

"Echo I" is a 100-foot-diameter passive communication satellite designed to reflect radio waves. A special beacon transmitter and power supply were designed for attachment to the external surface of this satellite. The transmitter, which produces an output of 5 to 10 milliwatts at 107.94 megacycles, is mounted along with silicon solar cells, batteries, and antenna on a 10-inch diameter printed circuit board. The package is 0.35 inch thick and weighs 11 ounces.

2400
Means, D. B. UNLIMITED POWER. Carnegie Tech. 25:26-27, Apr. 1961.

Methods of converting solar energy into electrical energy are discussed in terms of their acceptability as space power systems.

2401
Menetrey, W. R. and Burns, J. D. A SURVEY OF POWER SYSTEMS FOR SPACE APPLICATION. In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 56-66, New York, American Institute of Electrical Engineers, Dec. 1960.

Design characteristics and problem areas associated with some important solar power system components are emphasized. A general discussion is included regarding the power levels at which each system will be useful. Components and subsystems discussed in detail include photovoltaic cell arrays, the solar concentrator used in high temperature thermal systems, the absorber used for absorbing solar radiation and the thermionic diode.

2402
Mount Vernon Research Co., Alexandria, Va. SOLAR SPECTRUM SIMULATOR. (SPACE ENVIRONMENT SIMULATOR FOR TESTING SOLAR CELLS), by W. W. Stickney. 31 p., Nov. 1960. (WADD Tech. Rept. 60-847) (Contract AF33(616)-6935)

Objective of the work was to develop a device that would simulate the space environment so that the performance in space of solar cells and arrays of them could be realistically evaluated in the laboratory. The environment included three basic parameters: solar radiation, pressure, and thermal conditions.

An argon stabilized DC plasma arc was used as a light source to simulate the solar radiation in both color distribution and intensity from 0.2 to 2.0 microns wavelength. A vacuum chamber with liquid nitrogen cooled walls was built to simulate the effects on solar cells of pressure and thermal conditions in space.

2403
National Aeronautics and Space Administration, Washington, D. C. JUNO II SUMMARY PROJECT REPORT. VOLUME I EXPLORER VII SATELLITE. 356 p., illus., Jly. 1961. (Tech. Note D-608) (AD-259 999)

Networks and solar power systems for the Explorer VII-satellite are described.

2404
Osgood, C. C. and Winkler, S. H. OPTIMIZING THE DESIGN OF A SOLAR POWER SUPPLY SYSTEM. In American Astronautical Society. Advances in the Aeronautical Sciences. Proceedings, 6th, New York, 1960, p. 607-620, New York, Macmillan, 1961.

This paper, based on work done in the analysis, design development, and testing of silicon cell auxiliary power supplies, presents all the known significant parameters influencing a solar power supply design and shows how they can be integrated to yield an over-all design which is optimized for total weight and volume. Particular emphasis is placed on the energy storage problems and the determination and control of the thermal problems.

2405
Scott, W. C. DEVELOPMENT OF THE POWER SUPPLY FOR THE TRANSIT SATELLITE. In Snyder, N. W. ed. Space Power Systems, p. 49-78, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4).

The paper deals with the silicon photovoltaic converters, the rechargeable nickel-cadmium batteries, zinc-silver oxide batteries used in an early version, and the static conversion equipment. Requirements and test conditions are discussed and data are presented summarizing the telemetered data from the orbiting vehicles.

2406
SOLAR POWER FOR GLOBAL COMMUNICATION ON PROJECT ADVENT. The Sun at Work 6:19, Second Quarter 1961.

"Solar cells and a nickel-cadmium storage battery now under development by the U. S. Army will be used to power an instantaneous global communications system by means of satellites in stationary orbit. The primary objective of the satellite project, called Advent, is to conduct research and development to determine feasibility of a microwave communications system, using earth satellite communication repeaters in a synchronous, equatorial orbit.

"Two ground stations are planned for the system, one near Fort Dix, N. J., and the other near Camp Roberts, Calif. A Navy shipboard terminal will serve as a third station at sea operating in many parts of the world to test communications capabilities. The system will permit simultaneous transmission of high speed radio teletype and voice broadcasts.

"Power for the satellites will be provided by solar energy converted to electrical energy by thousands of solar cells built into two large laminated paddles. A sun tracker will keep the paddles continually oriented toward the sun. Nickel-cadmium batteries will provide power when the satellites are in the earth's shadow." Entire item quoted.

2407
Von Doenhoff, A. E. and Hallissy, J. M., Jr. SYSTEMS USING SOLAR ENERGY FOR AUXILIARY SPACE VEHICLE POWER. In Seminar on Advanced Energy Sources, 1958. Proceedings. . . p. 233-241, Fort Monmouth, N. J., 1959? (Contract DA 36-039-78064) (PB 151461) (AD 209301)

Solar energy conversion devices are discussed.

Also in Inst. Aeronaut. Sci. Rept. 59-40, 20 p., 1959.

2408
Westinghouse Electric Corp. Aerospace Electrical Department, Lima, Ohio. 4 KW SOLAR PHOTOVOLTAIC POWER SYSTEM DESIGN STUDY. 145 p., Jly. 31, 1961. (Bimon. Prog. Rept. 2) (Contract AF33(616)-8198)

A technical discussion of power system output characteristics, system configurations, solar cells, solar cell array, electrical conversion equipment, and orbit analysis.

2409
Williams, D. A., Chung, R., et al. COOLING SYSTEMS BASED ON SOLAR REGENERATION. Refrig. Eng. 66:33-37, 64-65, figs., Nov. 1958.

Intermittent adsorption or absorption refrigeration cycles, with regeneration by heating with solar energy have been proposed for small food coolers and space cooling in non-industrialized areas where refrigeration is not available for economic or technological reasons and where solar radiation is ample and reasonably dependable. This study of food coolers, part of a University of Wisconsin Solar Energy Research Program, provided certain performance data. Here the authors discuss: evaluation of potentially useful binary absorption systems, how operating variables affect ideal thermal performance of refrigerant-absorbent systems, illustrative experimental data on solar operation of two intermittent refrigeration systems, and analysis of experimental results of solar regeneration process as it affects refrigeration capacity.

2410
Wilson, E. D. POWER FROM THE SUN. Power 79:517, Oct. 1935.

Review on photovoltaic cells, with the statement that photovoltaic cells will be of no use to engineers until efficiency has been increased 50 times.

2411
Wolf, Martin. DEVELOPMENTS IN PHOTOVOLTAIC SOLAR ENERGY CONVERSION FOR EARTH SURFACE APPLICATIONS. 21 p. figs., New York, United Nations, Apr. 20, 1961. (E/CONF. 35/S/44)

An analysis indicates that present photovoltaic solar energy converters are economically feasible for earth surface application in remote locations and at low power levels. Some design hints are given for such systems. The recent improvements for silicon solar cells are reviewed, and the direction towards lower cost photovoltaic converters is indicated.

B. Photoemissive

2412
Aisenberg, S. THEORETICAL PERFORMANCE OF PHOTOEMISSIVE SOLAR ENERGY CONVERTERS. In Conference on Physical Electronics, 20th, Report, p. 115, Cambridge, Mass., Massachusetts Institute of Technology, 1960.

Brief summary.

2413
Benson, F. A. CHARACTERISTICS AND APPLICATIONS OF PHOTOELECTRIC CELLS. Illum. Eng. Soc. Trans. 23:127-142, 1958.

Deals first with the theory of photoemission and the properties of photoemissive cells. Various types of cathode which have been developed are described. Information is

then presented on gas-filled cells and photoelectric multipliers. Mention is made of color response, fatigue effects, dark current, noise, frequency response and associated circuits. The mechanisms and characteristics of various types of photovoltaic and photoconductive cells are included. The applications of photocells to photometry, optical phenomena and in reflectometers, fluorometers, refractometers, red photoelectric equipment is mentioned, and, finally, a large number of miscellaneous photocell applications are listed.

2414
But, Z. P. THE EFFECT OF SURFACE TREATMENT ON THE PHOTOEMISSION FROM GERMANIUM. Fiz. Tverdogo Tela 3:1137-1143, Apr. 1961. In Russian. Trans. in Soviet Phys. Solid State 3:826-829, figs., Oct. 1961.

The spectral and current-voltage characteristics of photoemission from germanium samples whose surfaces had been treated in various ways were studied. On the basis of this work, values for the photoelectric and thermoelectric work functions for each type of sample were obtained, and the magnitude of the surface potential was determined.

The role played by various methods of surface treatment and how they are reflected in the characteristics under investigation was evaluated.

2415
Notre Dame University, Notre Dame, Ind. FUNDAMENTAL RESEARCH IN PHOTOEMISSION. 24p., n.d. (Rept. TID -13047) (Contract A T (11-1)-274)

A summary is given of the work done on the program directed to the study of fundamental processes connected with the external photoelectric effect in metals and semiconductors. Discussions are presented of specific studies of vectorial photoelectric effect and optical properties of molybdenum, and photoemission from strontium and barium oxides on molybdenum. (Nuclear Sci. Abs. 15:22821, 1961)

2416
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. INTERNAL FIELD ASSISTED PHOTOEMISSION RESEARCH, by A. H. Sommer, E. K. Gatchell, et al. 21p., illus., Dec. 31, 1960. (Quart. Rept. 2) (Contract DA44-009-eng-4590) (AD-253 039)

Work was done on conventional and field induced photoemission. Under the first heading, experiments were made with thin films of the systems Ag-Sb-K, Ba-Si, and Ba-Sb. Work on field induced photoemission was pursued in the following directions: controlled method of Cs processing, surface films of CsI and Cs_3Sb, n-type surface layers on Ge and Si produced by heat treatment and epitaxial growth and exploratory experiments with the small band gap semiconductor InSb. (TAB p.129, May 15, 1961)

2417
Scheer, J. J. SOME PRELIMINARY EXPERIMENTS CONCERNING THE INFLUENCE OF BAND BENDING ON PHOTOELECTRIC EMISSION. Philips Res. Rept. 15:584-586, Dec. 1960.

The theory that p-type semiconductors should exhibit a higher photoelectric quantum efficiency then n-type semiconductors is verified by measurements of the photoemission from cesium-covered silicon surfaces.

2418
Spicer, W. E. CONSIDERATIONS OF PHOTOEMISSIVE ENERGY CONVERTERS. RCA Rev. 22:71-81, figs., Mar. 1961.

The efficiency of a solar-energy converter consisting of a [Cs] Na_2KSb emitter and an Ag-O-Cs collector is calculated taking into account the initial velocities of the photoelectrons but ignoring space

charge. Efficiencies between 2 and 2.1 per cent are obtained for output voltages between 0.8 and 1.6 volts. The efficiency increases as the percentage of blue and ultraviolet radiation in the source is increased. To minimize space-charge effects, the emitter-collector spacing must be of the order of 0.01 cm or less. From our present knowledge, it appears that photoemission energy converters will be insensitive to radiation damage.

2419
Wang, C. C. PHOTOELECTRIC EMISSION AND THE WORK FUNCTION OF SILICON. Dissertation Abs. 22:610-611, 1961.

PhD thesis, Stanford University, 1961.

Photoelectric emission is a field that has long been exploited with great interest. Even though work concerning photoelectric emission is always troublesome and painstaking, studies of photoelectric emission furnish valuable information about the interaction between light and matter. The techniques of photoelectric emission may also be used to investigate the optical and conduction properties of the materials from which the photoelectric emission is observed.

The photoelectric emission was observed from degenerate n-type silicon samples and p-type samples. An analysis of the spectral response yields information about the photoelectric response of the conduction electrons, the position of the surface states, and the band structure of the samples under investigation. The work reported here went further by applying the techniques of photoelectric emission to determine the difference in photoelectric work function between silicon samples of different doping. Even though the simple band model of solids is at best a poor approximation for degenerate samples of semiconductors, a study based on the simple band model of the effect of impurity content on the electron affinity is not altogether meaningless.

2420
Wooten, Frederick. PHOTOVOLTAIC EFFECTS IN Cs_3Sb FILMS. J. Appl. Phys. 32:1789-1790, figs., Sept. 1961.

This letter reports some photovoltaic effects observed in Cs_2Sb films, their implications with regard to band bending, and the influence of band bending on photoemission.

C. High Energy Processes

2421
Amphlett, C. B. THE PRODUCTION OF ELECTRICAL POWER FROM SEPARATED FISSION-PRODUCTS. J. Nuclear En. 1:173-180, figs., 1955.

A survey is made of the different methods described for producing electrical power from radioactive nuclides. The problem is examined in the light of nuclear physical and chemical considerations, and an evaluation is made of the potentialities of this method of producing power.

2422
BANTAM-WEIGHT POWER PACKAGE. Chem.Wk. 80:91-92, illus., Feb. 9, 1957.

Miniature nuclear battery, a joint development of Water Kidde Nuclear Laboratories, Inc. and Elgin National Watch Co. milestones a promising use of radioactive materials.

Its use is predicted for wrist watches, hearing aids and radios.

2423
Bomal, R. DETECTION OF NUCLEAR PARTICLES WITH SEMICONDUCTORS. Bull. Info. Sci. Tech. Paris. no. 34:p. 2-13, 1959.

In French a study was made of the applicability of semiconductors to the detection of nuclear particles and to the direct transformation of nuclear to electric energy. A

comparison is made between the performance of these new detectors and the existing instruments and between nuclear and chemical batteries.

2424
California Institute of Technology. Jet Propulsion Laboratory, Pasadena, Calif. EFFICIENCY OF FISSION ELECTRIC CELLS, by C. J. Heindl. 29p., May 25, 1961. (Tech. Rept. 32-105) (Contract NASw-6)

Electrical efficiencies are calculated for fission-electric cells of parallel plate, concentric sphere, and concentric cylinder geometries as a function of operating voltage and fuel layer thickness.

2425
Fairchild Engine and Airplane Corp., Farmingdale, N. J. A DIRECT NUCLEAR ELECTROGENERATOR. ANALYSIS OF CYLINDRICAL ELECTRODE CONFIGURATION, by Alfred Schock. 139p., illus., June 15, 1959. (AFOSR TN-59-590) (Contract AF49(638)15) (AD-216 812)

A system for the direct conversion of nuclear fission energy to high voltage electricity is examined. The system is based on the motion of highly charged fission fragments counter to a strong electric field. In this manner, part of the fragments' kinetic energy is converted into potential (electric) energy. The superiority of cylindrical over plane electrodes is explained, and the effect of various geometric and operating variables on system performance is analyzed. For various conditions, it is possible to achieve conversion efficiencies up to 13%, electric power densities up to 4.5 megawatts per cubic meter of reactor core, and neutron multiplication factors up to 2.1. However, these three performance parameters are shown to be mutually interdependent, and the choice of a design point must represent a compromise between their respective maximization. The optimum design parameters will depend on the intended application of the system.

2426
Monsanto Chemical Co., Mound Laboratory, Miamisburg, Ohio. NUCLEAR BATTERY-THERMOEOCUPLE TYPE, by B. C. Blanke. 30p., Dec. 31, 1958. (Quart. Prog. Rept. 8) (Rept. CF-59-1-54) (Contract R65-8-99811-SC-01-91)

A demonstration battery containing an 880-curie polonium-210 heat source was constructed and tested. The battery initially had an open circuit voltage of 23.6 volts, a maximum output of 161 milliwatts, and an overall efficiency of 0.57%. Details for the construction of the battery generator are given. (Nuclear Sci. Abs. 13:11099, 1959)

2427
Monsanto Chemical Co., Mound Laboratory, Miamisburg, Ohio. NUCLEAR BATTERY-THERMOCOUPLE TYPE, by B. C. Blanke. 17p., Mar. 31, 1959. (Rept. CF-59-6-33) (Quart. Prog. Rept. 9) (Contract R65-8-99811-SC-03-91)

A review was made of nuclides with $Z > 81$ (mainly α-emitters), which have specific activities sufficiently high to be used as heat sources. Previous restrictions on γ-radiation intensities and methods of production were considered, but consideration of nuclides which did not meet these restrictions was not excluded (Nuclear Sci. Abs. 14: 1637, 1960)

2428
Nachtigall, D. ISOTOPE-BATTERIES. (Die) Tech. 13:300-303, diags., Apr. 1958.

In German. A direct conversion of nuclear energy liberated by the decay of radioisotopes into electrical energy can be accomplished by: (1) the method of direct charge in

which charge carriers (α - and β - emitters) are collected by an electrode; (2) the method of contact potentials in which the ionized gases are formed by α -, β -, or γ -radiation and discharged by a metallic contact potential; (3) the thermoelectric method in which α -, β -, or γ -radiation is used to heat the junction point of two metals thus producing the thermoelectric effect; (4) the semiconductor method in which isotope radiation produces an electromotive effect by the p-n transition in semiconductors. The most commonly used radiation sources are Sr^{90}, Y^{90}, H^3, Po^{210} and Pm^{147}. The first three batteries have been known for some time, but the semiconductor battery is a very recent development and offers the most promising method of converting nuclear into electrical energy. By using Ge and Si semiconductors and 50 mc Sr^{90}, a current of 0.03 v and 25 μ amp was obtained. The optimal yield is 1%. It is suggested that an ideal radiation source, which is being produced in reactors in the USSR and England, would be Ni^{63}, a β -emitter having a half life of 85 years.

2429
Ohmart, P. E. A METHOD OF PRODUCING AN ELECTRIC CURRENT FROM RADIOACTIVITY. J. Appl. Phys. 22:1504-1505, Dec. 1951.

Initial efficiencies of conversion of radioactive energy to electrical energy that were achieved were only of the order of $1x10^{-11}$ percent when an air cell was excited by gamma radiation from a 24.8 milligram radium source. In order to improve these efficiencies the co-axial type cell was constructed.

2430
Radiation Research Corp., West Palm Beach, Fla. NUCLEAR BATTERIES, by J. H. Coleman et al. 3 issues, 1953, 1954. (Quart. Prog. Repts. 5, 7 and Final) (Contract DA36-039-sc-42564) (AD-22 386, AD-72 778, AD-57 693)

Research was concerned with the utilization of radioactive energy as a source of electrical energy for use as a portable battery.

2431
Radiation Research Corp., West Palm Beach, Fla. NUCLEAR BATTERIES, by J. H. Coleman, et al. 4 issues, 1954, 1955. (Quart. Prog. Repts. 1, 2, Repts 11, 12) (Contract DA36-039-sc-64479) (AD-63 916, AD-63 847, AD-81 580, AD-71 804)

Further studies are presented relative to development of nuclear batteries.

2432
Radiation Research Corp., West Palm Beach, Fla. NUCLEAR BATTERIES, by J. H. Coleman et al. 3 issues, Oct. 1955, Apr., Jly. 1956. (Repts. 13, 15, 16) (Contract DA36-039-sc-70117) (AD-84 399, AD-112 970, AD-112 969)

Characteristics of a nuclear battery are described.

2433
Radiation Research Corp., West Palm Beach, Fla. NUCLEAR BATTERIES, by J. H. Coleman, et al. 4 issues, 1957. (Quart. Prog. Repts. 1, 2, 3 and Final) (Contract DA36-039-sc-73115) (AD-138 426, AD-145 426, AD-160 419)

Work on strontium, tritium, and krypton batteries is given, and effort is reported on development of tritium batteries.

2434
Rukman, G. I., Tychinskii, V. P., and Yukhvidin, Ya. A. A METHOD OF PRODUCING POWER FROM BETA-ACTIVE ISOTOPES. Trudy Nauch. Issled. Inst. Ministerstva Radiotekh. Prom. SSSR. no. 6:3-8, 1956.

In Russian. An atomic energy source is suggested, based on the charge accumulation created by β - radiation in an electric capacitor. A charged capacitor is periodically discharged by a switching device onto an impulse transformer, the secondary winding of which supplies a load. A scheme of an atomic

battery is also presented, its power and efficiency are calculated on the basis of a 10^5 curie β-source activity, with an average β-particle energy of 100-kev, and a 100-$\mu\mu$f capacitor, the optimum charging time that corresponds to the maximum efficiency (20.5%) is 20 microseconds, the capacitor voltage is 70 kv, and the mean output power is 13 w. With a 10:1 transformer ratio, the equivalent battery resistance is on the order of hundreds of ohms. The S^{35} sulfur isotope, with an average energy of about 100 kev and a half-life of 87.1 days, is recommended as a source of β-radiation. (Nuclear Sci. Abs. 14:781, 1960)

2435
Sukhov, B. P. ATOMIC MICRO-BATTERIES. Nauka i Zhizn no. 7, p.71, 1958.

In Russian. The utilization of atomic batteries as motive power for wrist watches is considered.

2436
Yamanaka, Chiyoe, et al. FUNDAMENTAL STUDY OF THE ATOMIC BATTERY. Osaka Univ. Tech. Repts. 8:233-241, diags., Oct. 1958.

In English. Electron-voltaic effects in diffused p-n junctions of Ge were obtained by diffusing As at 210°C in 10^{-5} Hg vacuum on a p-type Ge, doped with In, of 3 Ω cm resistivity. A thin Au wire was attached to the surface of this junction by soldering. The p-n junction was irradiated with a clinical 50-mc Sr^{90}-Y^{90} source, and the electron-voltaic effect was measured from room temperature down to -78°C. The general condition of an atomic battery was similar to that of a solar battery except that the atomic battery offers the possibility of current multiplication but presents the problem of radiation damage in the crystal lattice caused by ionizing radiation. At room temperature no radiation damage was observed. The junction and radiation damage of a Si-based atomic battery was studied also.

V. MAGNETOHYDRODYNAMICS

A. General Information

2437
General Electric Co. Flight Propulsion Laboratory, Cincinnati, Ohio. ON THE POSSIBILITIES OF ELECTRICAL POWER GENERATION BY MAGNETOHYDRODYNAMIC DEVICES, by R. E. Neitzel. 44p., Nov. 20, 1958. (Rept. DF58AGT853)

Devices which take energy from a conducting gas and convert it to electricity by the interaction of the gas velocity and a magnetic field are examined. The factors which affect the output-size relationship and the efficiency level are studied, the most important being conductivity of the gas, the gas velocity, and magnetic field strength. Problem areas and potentialities are then discussed.

2438
Huth, J. H. ELECTRICAL POWER FROM ROCKETS. Paper presented at the Semi-Annual Meeting of the American Rocket Society, Los Angeles, May 9-12, 1960. 14p., New York, American Rocket Society, 1960. (Preprint 1147-60)

The characteristics of magnetohydrodynamic generators, as applied to ground-base chemical-rocket exhausts, are discussed. Simple open-cycle units can have ultimate efficiencies up to 40%, and can provide electrical power on very short notice. More specifically, rocket-powered MHD generators are suited to applications requiring hundreds or thousands of electrical megawatts for a few minutes. Within this range power densities (including the magnet) of at least 250 kw/ft^3 can be foreseen. The main problems center about developing suitable materials for operation near 2000 to 3000°K. No moving parts are required in the MHD generator, where these temperatures manifest themselves. (Nuclear Sci. Abs. 15:7923, 1961)

2439
Jenny, E. THE FOUR MOST IMPORTANT METHODS OF DIRECT ENERGY CONVERSION. Schweiz. Bauz, 79:383-390, 1961.

In German. The magnetohydrodynamic (MHD) generator is discussed. The working principle and simplified theory are outlined. Constructional problems, proposed designs and some existing installations are described, including those of AVCO, General Electric, and Westinghouse. MHD generators can attain an efficiency of over 50%, but the material problem is an important one, working conditions are severe and rate of erosion very high. (Index Aero. 17:56, Aug. 1961)

2440
Kantrowitz, Arthur. POWER IN THE SPACE AGE. Astronautics 6:54-55, 118-119, Oct. 1961.

The article indicates in what way the current enthusiasm for magnetohydrodynamics stems from close relationship both to nuclear energy and space flight.

2441
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. MAGNETOHYDRODYNAMICS AND ENERGY CONVERSION. 2 issues, Mar. 15, June 15, 1961. (Tech. Prog. Repts. 2, 3) (Contract AF33(616)-7624)

Discussed are magnetohydrodynamic ac generator with gas losses, magnetic reflection of a shock-produced plasma, summary of some results in the study of decaying magnetofluid-dynamic flows, fuel cells, electrohydrodynamic surface waves and instabilities, and performance characteristics of cesium thermionic converters.

2442
Sutton, G. W. and Steg, L. THE PROSPECTS FOR MHD POWER GENERATION. In Snyder, N. W. ed. Energy Conversion for Space Power, p. 625-661, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, v1.3)

It is pointed out that recent advances in "low" high temperature technology have generated a number of pertinent theoretical and experimental studies. The present situation is summarized and the more significant problem areas are outlined.

B. Principles

2443
Aerospace Corp., El Segundo, Calif. MAGNETOHYDRODYNAMIC VORTEX POWER GENERATION, by W. S. Lewellen. 32p., illus., Mar. 15, 1961. (Rept. TDR-594 (1203-01)-TN-2) (Contract AF04 (647)594) (AD-256 797)

The possibility of using a hydrodynamically driven vortex to convert thermal energy into electrical energy is investigated. Two promising areas of application as a space power generator are uncovered. The first is as a short term power supply when used in conjunction with a rocket exhaust and the second is a long term power supply when used in a closed cycle nuclear system. Estimates of the operating characteristics of the MHD vortex in both of these environments are presented. It is concluded that the open cycle MHD vortex should be competitive with other systems for operating times between a few seconds and an hour at power levels above a few kilowatts. It is also concluded that replacing the turbo-alternator package in a closed cycle nuclear system with an MHD vortex provides a potential increase in the specific power output (KW/lb) of the order of 100% for power levels above a few hundred kilowatts.

2444
Dahlberg, Erling, Hubers, K., and Lundquist, Stig. MAGNETOHYDRODYNAMISK PRODUKTION AV ELEKTRISK ENERGI. (MAGNETOHYDRODYNAMIC GENERATION

OF ELECTRIC ENERGY). Tek. Tid. 91:85-89, Feb. 3, 1961.

In Swedish. Discussion of the principles underlying the magnetohydrodynamic generation of electric energy. Considered are conductivity, generators, combustion chambers, and preheating of air; some current experiments are briefly mentioned. (Intern. Aerospace Abs. 1:61-7203, Sept. 1961)

2445
Hurwitz, H., Jr., Kilb, R. W., and Sutton, G. W. INFLUENCE OF TENSOR CONDUCTIVITY ON CURRENT DISTRIBUTION IN A MHD GENERATOR. J. Appl. Phys. 32:205-216, Feb. 1961.

Magnetohydrodynamic generators may operate under conditions such that the product of electron cyclotron frequency and mean collision time is not small compared with unity. Accordingly, the electrical conductivity is a tensor rather than a scalar quantity. The influence of tensor conductivity on the electrical current distribution is investigated in two idealized situations, one pertaining to the entrance and exit regions of the generator and the other to the region near segmented electrodes. The calculations predict modifications of the internal impedance of the generator which can be described in terms of increases in the effective duct length and width. (Sci. Abs. 64A:3051, 1961)

2446
Rosa, R. J. and Kantrowitz, Arthur. MAGNETOHYDRODYNAMIC ENERGY CONVERSION TECHNIQUES. In Seminar on Advanced Energy Sources, 1958. Proceedings...p. 203-207, Fort Monmouth, N. J., 1959? (Contract DA36-039-78064) (PB 151461) (AD 209301)

MHD is compared with other power generating systems and its specific characteristics are indicated. Some experiments are described for the purpose of increasing understanding of conductivity and MHD flow phenomena.

2447
Sleight, P. POWER FROM IONIZED FLUIDS. Compressed Air Mag. 65:20-22, Mar. 1960.

Principles of magnetohydrodynamics (MHD); ionized gas becomes electrical conductor and generates electricity when passed through magnetic field. In production of electricity, MHD generator substitutes high temperature ionized gas for armature; ionization needs 3000 to 5000°F temperature; ionization by coal-cycle in coal-burning plant; use of nuclear reactor for heating and ionization of gases; possibilities of commercial MHD power generation. (Eng. Index p. 761, 1960)

2448
Swift-Hook, D. T. MAGNETOHYDRODYNAMIC POWER GENERATION. Discovery 22:326-333, illus., Aug. 1961.

Magnetohydrodynamic (MHD) power is produced directly by passing a hot conducting gas through a magnetic field. This method of generation offers the prospect of much higher thermal efficiencies than conventional power stations, and developments in rocketry and thermonuclear research have increased the chance of solving the technical problems. But much remains to be done.

2449
Tao, L. N. ON THEOREMS OF MINIMUM ENERGY DISSIPATION IN MAGNETOHYDRODYNAMICS. Appl. Sci. Res. 9B:161-168, 1961.

Navy-sponsored discussion of some theorems on MHD energy dissipation. It is shown that, under certain conditions, the steady motion of an electrically conducting incompressible fluid has an absolute minimum of energy dissipation, and that, for the same conditions, an unsteady motion with steady boundary conditions always tends to its steady state, which is stable as well as unique. (Intern. Aerospace Abs. 1:61-7000, Sept. 1961)

C. Plasma Properties

2450
von Fredersdorff, C. G. MAGNETOHYDRODYNAMIC GENERATION OF ELECTRIC ENERGY. Power 105:66-69, May 1961.

After a discussion on the principles of MHD generation, the design of MHD nozzles is briefly considered.

2451
GASEOUS PLASMA ACHIEVED THROUGH CHEMICAL METHOD. Space Age News 4:6-7. Oct. 9, 1961.

Low-temperature plasma generated by combination of ammonia/metallic sodium solution exhibits stability for periods in excess of seven minutes. One of its uses is indicated as being in the MHD power conversion field.

2452
Hellund, E. J. THE PLASMA STATE. 199p., New York, Reinhold Publishing Corp., 1961.

The magnetic, electric, physical, and mechanical properties of plasmas are reviewed. Chemical reaction such as ionization and wall reactions, atomic reactions such as energy exchange processes, and nuclear fusion reactions in plasma are discussed. The magnetohydrodynamic and electrohydrodynamic aspects of plasmas are examined. Plasma applications, such as cesium vapor converters, MHD generators, and plasma thermocouples are outlined. (Nuclear Sci. Abs. 15:23024, 1961)

2453
Kantrowitz, Arthur. MAGNETOHYDRODYNAMIC POWER GENERATION. In American Power Conference. Proceedings, March 29-31, 1960, Chicago, Ill., vl. 22, p. 61-67, Chicago, Illinois Institute of Technology Press, 1960.

Shock tube experiments were performed to investigate the feasibility of a magnetohydrodynamic (MHD) generator; results are presented for the gas conductivity vs. Mach number, plasma retardation by the magnetic field, and annular gas current. It is concluded that the behavior of gases at high temperatures can be predicted. A MHD generator using argon seeded with K_2CO_3 was constructed and curves of its characteristics are presented as a function of current. The MHD generator was then evaluated for practical power generation; gas conductivity and power curves as a function of temperature were derived. Temperatures ~ 2000°K and a minimum size are required for the generator for power generation. Both nuclear and combustion cycles for heating the gas are considered, and it is concluded that the combustion cycle entails less serious problems from the materials standpoint. The capital costs of a MHD generator reaching temperatures ~ 3600°F were analyzed and found to be competitive with those of a steam plant.

2454
McCune, J. E. and Donaldson, C. duP. ON THE MAGNETOGASDYNAMICS OF COMPRESSIBLE VORTICES. In Snyder, N. W. ed. Energy Conversion for Space Power, p. 715-741, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3).

Basic solutions are presented for the steady spiral motion of a viscous electrically conducting gas, moving either inward or outward in the presence of an axial magnetic field between two concentric porous electrodes. Results presented indicate that such a device may be useful as a power generator. An appropirate efficiency for the device operating as a power generator is defined, and the inflow and outflow configurations compared.

2455
Republic Aviation Corp. Plasma Propulsion Laboratory, Farmingdale, N. Y. THE EFFECT OF

VARIABLE PLASMA CONDUCTIVITY ON MHD ENERGY CONVERTER PERFORMANCE, by W. B. Coe and C. L. Eisen. 20p., Oct. 1960. (Tech. Rept. 60-16) (AFOSR-TN-164) (Contract AF49 (638)-552) (AD254674)

An investigation was made in order to obtain solutions to a set of differential equations governing the performance of the magnetohydrodynamic (MHD) energy converter with the electrical conductivity of the plasma dependent on its local thermodynamic properties. Cesium vapor was chosen as the working fluid and the performance computed for two values of entrance stagnation temperature, 2000 and 5000°K. The required entrance flow Mach number for maximum power density increased as the entrance stagnation temperature was increased. For the temperatures studied, the required entrance Mach number was always subsonic. The attainable power density increased sharply with increases in entrance stagnation temperature. (Nuclear Sci. Abs. 15:16555, 1961)

2456
Yano, Syukoro and Hiramoto, Tatsumi. MAGNETOHYDRODYNAMIC POWER GENERATION. Atomic En. Soc. Japan J. 3:296-307, Apr. 1961.

In Japanese. Methods for calculating the electrical conductivity of hot ionized gases in a MHD generator are reviewed and discussed, using the Boltzmann equations for incompletely ionized gases. The present status of theoretical and experimental work in the development of a MHD generator in the U.S.A. is reviewed, with a brief report of researches by the Japan Atomic Energy Research Institute. Prospects and technical problems of MHD power generation using nuclear fuels are discussed. MHD power generation by the future nuclear reactor operating at high temperature is discussed. (Nuclear Sci. Abs. 15:21263, 1961)

D. Devices

2457
Bernstein, I. B., Fanucci, J. B. et al. AN ELECTRODELESS MHD GENERATOR. In Second Symposium on the Engineering Aspects of Magnetohydrodynamics, University of Pennsylvania, March 9-10, 1961. Co-sponsored by American Institute of Electrical Engineers, Institute of Aerospace Sciences, and Institute of Radio Engineers.

In view of the well-known shortcomings of the dc MHD generators, the feasibility of adapting the theory of ac induction generators to MHD power generation is investigated. This concept immediately removes the problem of electrode erosion, and, further, ac electric power is obtained directly without the need for auxiliary converter equipment. Several configurations are possible. (Astron. Info. Abs. 3:3536, 1961)

2458
Boucher, R. A. and Ames, D. B. END EFFECT LOSSES IN dc MAGNETOHYDRODYNAMIC GENERATORS. J. Appl. Phys. 32:755-759, figs., May 1961.

In this paper the end effect loss in a dc magnetohydrodynamic generator with rectangular cross section is considered. The case for nonconducting walls is examined, and a simple expression for the losses in terms of the maximum power output is obtained. The end effect loss is compared to viscous and turbulent flow losses and it is shown to be the predominant loss over a wide range of operating conditions.

2459
California Institute of Technology. Jet Propulsion Laboratory, Pasadena, California. A TWO-FLUID MAGNETOHYDRODYNAMIC CYCLE FOR NUCLEAR-ELECTRIC POWER CONVERSION, by D. G. Elliott. 14 p., June 30, 1961. (Tech. Rept. 32-116) (Contract NAS w-6)

Describes a two-fluid cycle for MHD conversion - one fluid being a gas

for the thermal-to-kinetic conversion, and the other a conducting liquid for the kinetic-to-electric conversion.

2460
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume VIII: OTHER DEVICES, by R. Wall, D. Erway, et al. 145p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. VIII) (Contract AF33(616)6791) (AD-256 882)

The performance characteristics are described of several auxiliary components useful in space power systems including orientation mechanisms, pumps, and static conversion and regulation devices. In addition, the MHD generator is analyzed as a thermal energy converter, and the possibilities of using beamed electromagnetic power are discussed. Weight, efficiency, power requirements, and other design characteristics of the auxiliary equipment are presented in empirical and analytical form. It is shown that beamed electromagnetic power does not appear useful until major breakthrough in antenna design and theory are achieved. The theoretical relations describing the MHD generator and the possibilities of its eventual use in thermal systems are described.

2461
Gourdine, M. C. NO CLUTCH, NO TRANSMISSION, NO BRAKES. Soc. Automotive Engrs. J. 69:50-51, illus., May 1961.

Paper 312C. Magnetohydrodynamics could be used to propel a car. The vehicle would run on regular gasoline, and would need no ignition system, clutch, transmission, differential, or brakes. This development is not just around the corner, but it is an intriguing possibility for the future.

A MHD-motor-generator would provide individual drive to all four wheels. Braking would be accomplished by reducing the fuel supply or by throwing the entire system into reverse. If combustion were incomplete, an MHD afterburner might prove practical for smog suppression.

2462
Hawley, R. MAGNETOHYDRODYNAMIC POWER GENERATION. Inst. Elec. Engrs. J. 31:63-69, Dec. 1960.

Suggested types of magnetohydrodynamic power generators are discussed. Design studies on suitable thermodynamic cycles are mentioned. The conductivity of gases at high temperatures is reviewed as are the possible methods of obtaining the required conductivity in these types of generator. A rough estimation is made of the size of the duct in the case of a magnetohydrodynamic generator. Experimental generators and results obtained from them are covered as is the extent of present-day research in this subject. (Sci. Abs. 64B: 2208, May 1961)

2463
McIlroy, William and Kunen, A. E. MHD APPLICAT.ONS FOR SPACE AND GROUND POWER. International Congress and Exposition of Automotive Engineering, Jan. 9-13, 1961, Detroit, Mich. 21p. New York Society of Automotive Engineers, 1961. (Preprint 312B)

USAF-Navy-sponsored discussion of working problems of pulsed plasma generators, and of the importance of specific impulse and energy conversion efficiency in the selection of a working engine. The development of the plasma pinch engine is presented as an example of an accelerator in the development stage. The application of MHD to electrical generation is described briefly. A short description is also given of analytical work that has been done on the application of a magnetic field to a high power thermionic converter to increase its efficiency. (Inter. Aerospace Abs. 1:61-2622, Apr. 1961)

2464
MAGNETOHYDRODYNAMIC GENERATOR WITH ROCKET ENGINE. Przeglad Tech. no. 45, p. 10, 1960.

Not examined. The magnetohydrodynamic theory and operating principle of the MHD magnetohydrodynamic generator are presented. The first such generator was designed at the end of 1959. Energy of strongly ionized air, heated to 2700°C, was directly converted into electric energy, and within 5 seconds 1 kw was produced. On the basis of this positive result, it is planned to build a big MHD generator and have it driven by a small rocket engine. (Nuclear Sci. Abs. 15:22407, 1961)

2465
Mullaney, G. J. and Dibelius, N. R. SMALL MHD POWER GENERATOR USING COMBUSTION GASES AS AN ENERGY SOURCE. ARS J. 31:555-557, Apr. 1961.

Investigation of the fundamental principles of magnetohydrodynamic power generation, using a device based on the electrical conductivity of partially ionized flame gases seeded with potassium. Potassium concentration was varied from 1% to 6% by weight of the combustion mixture. The power output of the generator increased as the square root of the potassium concentration, following the trend established in conductivity experiments made earlier. The output power was 55% of the calculated value. Power extraction was transverse to both magnetic field and gas flow, and continuous electrodes were employed.

2466
Pratt and Whitney Aircraft Co., East Hartford, Conn. MAGNETOHYDRODYNAMIC POWER GENERATOR FEASIBILITY STUDY. 223p., Feb. 1961. (Rept. 1940) (RADC-Tech. Rept. 61-104) (Contract AF30(602)2268) (AD-257 619)

Open-cycle chemically heated and closed-cycle nuclear-heated generators were investigated, most of the effort being devoted to the former.

2467
Sutton, G. W. DESIGN CONSIDERATIONS OF A MAGNETOHYDRODYNAMIC ELECTRICAL POWER GENERATOR. SAE-AFOSR Astronautic Symposium, Los Angeles, Calif., Oct. 12-14, 1960, Preprint 230F.

Study considering the various requirements for a successful MHD generator. The requirement that thermal energy be transformed into kinetic energy implies that the only suitable working fluids are gases. To achieve sufficient electrical conductivity of gases, so that the generator length be reasonable, temperatures of 5,000°F are necessary. It is found that generator length can be decreased by increasing the magnetic field or decreasing operating pressure. This, however, is limited by the Hall effect. Full consideration is given to the losses which must be carefully dealt with in order to design a successful MHD generator. These losses are exhaust temperature, entropy loss, magnet power, wall cooling, and end losses. It is found that none of these problems appears insurmountable, so that the design of a practical MHD generator should be feasible. (Intern. Aerospace Abs. 1:61-2388, Apr. 1961)

2468
Way, Stewart. EXPERIMENTS RELATING TO GENERATION OF POWER BY MAGNETOHYDRODYNAMICS. In Snyder, N. W. ed. Energy Conversion for Space Power, p. 671-694, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry vl. 3)

Some recent studies with a combustion gas MHD generator are described.

VI. ELECTROCHEMICAL PROCESSES

2469
Daniel, A. F. ELECTROCHEMICAL CONVERSION OF ENERGY. In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 41-45, New York, American Institute of Electrical Engineers, Dec. 1960.

Characteristics of electrochemical systems of importance to space applications are considered. They are: dry primary batteries, wet primary batteries, storage batteries, molten electrolyte batteries or thermal batteries, primary fuel cell batteries, and regenerative fuel cell batteries.

2470
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume VI, CHEMICAL SYSTEMS, by W. R. Menetrey and J. Chrisney. 202p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. VI) (Contract AF33(616)6791) (AD-257 358) (PB 171 863)

This volume discusses primary and secondary batteries, primary and regenerative fuel cells, reciprocating engines using H and O bipropellant, turbines, and cryogenic storage of H and O.

2471
Lukovtsev, P. D. ELECTROCHEMICAL SOURCES OF ELECTRIC CURRENT. Priroda 48:22-28, Dec. 1959.

In Russian. Electrochemical sources of electric power are relatively insensitive to external effects due to temperature, shocks, vibrations, moisture, etc. For this reason, electrochemical sources of current can be used to supply electric power in connection with many applications for which other sources of power are unsuitable. This includes applications on artificial satellites and pilot balloons.

2472
Morehouse, C. K. A REVIEW OF THE STATE OF THE ART AND FUTURE TRENDS IN ELECTROCHEMICAL BATTERY SYSTEMS - II. SOME NEW DEVELOPMENTS. In Seminar on Advanced Energy Sources, 1958, Proceedings... p. 55-68, Fort Monmouth, N. J., 1959? (Contract DA36-039-SC-78064) (PB 151461) (AD 209301)

A review is given of the material sources, new types of dry and reserve batteries, and suggestions made as to where further research is warranted.

A list of 52 references on batteries is included.

2473
Pitts, J. N., Jr., Margerum, J. D., and McKee, W. E. PHOTOCHEMISTRY AND SPACE POWER GENERATION. ARS J 31:890-896, Jly. 1961

Discussion of fundamental photochemical principles and processes relative to: (1) photogalvanic solar batteries, and (2) solar regenerative cells. The necessity of intensive fundamental and applied research in these areas is indicated.

Also issued as ARS Preprint 1180-60.

A. Fuel Cells

1. General Information

2474
Adams, A. M. FUEL CELLS. Heat. 22:75-78, 82, Apr. 1960.

Thermodynamic basis, electrochemical principles and design considerations of unit having two electrodes and ionic conductor. Features and operation of Kordesch, Bacon and Redox low temperature cells for possible use in power generation, household power, space heating and air conditioning. Design of high temperature cells

applicable in radar, traction applications, and power supplies in submarines and satellites. (Eng. Index p. 506, 1960)

2475
Adams, A. M. FUEL CELLS. I: PRINCIPLES, EARLY FUEL CELLS, HIGH-TEMPERATURE CELLS. II: LOW-TEMPERATURE CELLS: FUTURE DEVELOPMENTS. Chem. Process Eng. 35:199-203; 238-240; 246, 1954.

Examination of general principles involved in design of fuel cells or primary cells for electrochemical oxidation of fuels. Various types of such cells proposed described. Cells classified into high- and low-temperature ones. Low-temperature hydrogen-oxygen cells have been most fully developed and small-scale industrial application of these is expected. Deals in particular with the fuel utilization and design of high-temperature cells. Theory and descriptions of the Davtyan low-temperature hydrogen cells, the Bacon high-pressure H-O cell (porous Ni electrodes, Ni-plated steel covers), Redox cells. Factors likely to affect future development.

2476
Adams, D. R. et al. FUEL CELLS; POWER FOR THE FUTURE. 160p., Cambridge, Mass., Fuel Cell Research Associates, 1960.

Originally written as a partial fulfillment of the requirements for the degree of Master in Business Administration at the Harvard Business School. One objective was to determine the commercial and engineering practicality of present and potential fuel cells. This has been done by establishing a method of evaluating fuel-cell developments, and comparing present and future fuel cells with conventional sources of power in various power applications. A second objective was to investigate the status of fuel-cell technology and present the technical operations and limitations of fuel cells, and to investigate the various chemical fuels used in fuel cells. (Tech. Book Rev. Index 27:41, Mar. 1961)

2477
ALLIS-CHALMERS MARKETS MODEL FUEL CELL. Res/ Devlpmt. 12:16-17, Mar. 1961.

The article tells of a working model fuel cell demonstrator for instructional and educational purposes that directly converts chemical energy into electrical energy.

2478
ALLIS-CHALMERS SHOWS FUEL CELL-POWERED TRACTOR. Elec. World 152:78, illus. Oct. 26, 1959.

"One of the potential uses of electric power from fuel cell was demonstrated recently by Allis-Chalmers when a tractor was put through its paces, powered by cells still in the laboratory-stage of development.

"In the tractor, A-C uses 1008 of these cells, which, operating on a mixture of gases, largely propane, deliver a total electrical output of 15 kw. A standard 20-hp dc motor drives the 5270-lb tractor to provide 3000-lbs pull at the draw bar. Each fuel cell is 1/4 in. thick and 12-in. square, with a no-load output of lv.

"Efficiency of the present fuel cells is 60%, A-C says, but they look forward to efficiencies of 80% and compare it with the conventional heat engine figure of about 40%. While A-C has no commercial plans right now with regard to these cells, they do foresee the time when fuel cells could be used in central stations to provide peaking power. Gases used as fuel would be generated during off-peak hours by reversing the cell cycle." Entire item quoted.

2479
ARMY, MARINES GETTING NEW FUEL CELL POWER. Sci. News Ltr. 77:295, May 7, 1960.

Concerns a portable fuel-cell power plant for the U.S. Army Signal

Corps and the U.S. Marine Corps. The power plant will have no major moving parts but will produce 200 watts of direct current at 24 volts. It can be carried by a soldier on his back to power portable radar systems that can detect enemy movements through darkness and fog.

2480
ARMY ROUNDS UP FUEL CELL PROGRESS. Mach. Design 32:31-37, 1960.

The broad definition of a fuel cell - an electrochemical device in which part of the energy derived from a chemical reaction, maintained by a continuous supply of chemicals, is converted into electricity - covers many different systems. The Army classifies the cells into five main types: hydrogen-oxygen, molten-salt electrolyte, redox, regenerative, and consumable electrode.

2481
Austin, L. G. FUEL CELLS. Sci. Am. 201:72-78, illus., Oct. 1959 Excerpts in Air Cond. Heat. & Vent. 56:16, 1959.

Devices under development are described that convert energy directly into electricity, thus circumventing the inefficiency of the heat engines used to drive electric generators.

2482
Bacon, F. T. FUEL CELLS: WILL THEY SOON BECOME A MAJOR SOURCE OF ELECTRICAL ENERGY? Nature 186:589-592, 1960.

A review of present-day fuel cells, the disadvantages and advantages of fuel cells, and practical demonstrations of the application of fuel cells.

2483
Balaceanu, J. C. LE PETROLE, COMBUSTIBLE ELECTROCHIMIQUE. (PETROLEUM AS ELECTROCHEMICAL FUEL). Inst. Franc. Petrole & Ann. Combus. Liquides. Rev. 15:1465-1479, Oct. 1960.

In French. Problems of fuel cells studied in laboratories of French Petroleum Institute. (Eng. Index p. 507, 1960)

2484
BATTERY-POWERED CARS HAVE NEW LOOK. Indus. Eng. Chem. 52:28A, Feb. 1960.

Illustrated notes on U.S. progress and developments in battery-powered cars, with particular emphasis on the "Nu-Klea" design powered by Pb-acid batteries of conventional design. Reference to fuel cell developments is also included.

2485
BIOCHEMICAL CONCEPT CITED AS FUEL RESEARCH ADVANCE. Army Res. & Devlpmt. 2:7, Oct. 1961.

Brief summary of talk given by E. M. Cohn at the Energy Conversion Symposium of the 12th International Astronautical Congress. The concept of the biochemical fuel cell appears to be branching out into three distinct directions: (1) attempts at imitation of biological processes; (2) possible in vito use of biological materials as catalysts; and (3) utilization of primitive forms of life to decompose organic material and obtain fuels suitable for use in fuel cells.

2486
Bloch, O. LES PILES À COMBUSTIBLES. (FUEL CELLS). Inst. Franc. Petrole et Ann. Combus. Liquides. Rev. 14:1261-1274, Oct. 1959.

In French. Features of fuel cells, types of fuel cells proposed and their possible uses. (Eng. Index p. 499, 1959)

2487
Brancker, A. V. CONVERSIONS OF HEAT INTO WORK. Petrol. 23: 56-59, Feb.; 105-108, 114, Mar. 1960.

Direct conversion processes include fuel cells and hydrogen carbon

monoxide oxygen cells where gaseous products from hydrocarbons or coal can be used. Essential part of heat engine cycle is unavailable heat discharged to refrigerator; although efficiencies of as high as 70% have been claimed for direct conversion processes using fuel cells, there are still several causes of inefficiency. (Eng. Index p. 506, 1960)

2488
Central Electrical Authority, Leatherhead, Eng. FUEL CELLS, by A. M. Adams. 1/4 in. thick, Oct. 25, 1950. (Lab. Rept. 377) (DC 45,937)

The principles, theoretical advantages and various types of fuel cells are described. Criteria for assessing the possible usefulness of cells are suggested and recent work is examined. It is concluded that the published data are insufficient on which to judge the economics of proposed cells; both a fundamental study of cell reactions and additional measurements on actual cells are required. Gas cells operating at about 700° C, if satisfactory, would appear to have the widest field of application.

2489
Chambers, H. H. FUEL CELLS. N.E. Coast Inst. Engrs. & Shipbdrs. Trans. 77:379-388, Apr. 1961.

Very considerable effort which is being devoted to fuel cells, especially in the United States, is expected to lead to commercial exploitation within the next five years. Unless there is a major breakthrough in the near future, the first cells for operation on commercial hydrocarbon fuels will be high-temperature cells running above 400°C, and, as they will not be capable of rapid start-up, they are unlikely to be used for such things as powering motor cars. They will be quite suitable for any use where the power demand is steady or intermittent but without long idle periods. The first commercial batteries are likely to replace small motor generator sets of up to 20 kW output. Larger units may be developed fairly soon after the first appearance of small units. The future for large central power-station generation is uncertain. It is too early to predict capital costs, but in view of the high operating efficiency and versatility, it is likely that fuel batteries will begin to become competitive before the capital cost approaches that of diesel generators. Parallel development of other types of cell, including low-temperature cells, is probable, and such cells will be used for special purposes where the relatively high cost of specialized fuels can be tolerated. (Fuel Abs. & Current Titles 2:2936, 1961)

2490
Chambers, H. H. FUEL CELLS. A REVIEW OF CURRENT PROGRESS. Beama J. 68:45-50, May 1961.

The present state of the art is reviewed; problems which have to be solved are outlined; advantages are indicated; and future prospects are predicted, namely that commercial units will begin to appear on the market within the next five years.

2491
Cohn, E. M. FUEL CELLS - DIRECT CONVERSION OF CHEMICAL TO ELECTRICAL ENERGY. Electron. Design 9:62-67, Feb. 15, 1961.

Discussion of the types, basic design, performance, and state of development of fuel cells. Fuel cells for operation at elevated temperatures are also considered. It is pointed out that efficiencies up to 80% are achievable. Infinite shelf life, high power per weight and volume, plus lack of noxious by-products are some of the features advantageous for many military, industrial, and missile applications. (Intern. Aerospace Abs. 1:61-2392, Apr. 1961)

2492
Corfield, Guy. FUEL CELL. Gas. 34:15, Oct. 1958.

Describes a fuel cell developed by the National Carbon Company to be used by the Army to power a portable field radar assembly. Further potentialities are indicated.

2493
DE SOTO STUDIES FUEL CELL AS POWER SOURCE FOR CAR. Automotive Indus. 120:20-21, Feb. 1, 1959.

Concerns an idea advanced by engineers involving the use of an electrochemical fuel cell and four small electric motors to power a passenger car. It is noted that three major breakthroughs will be needed to shorten the time factor in development: (1) a better way to store and supply hydrogen and oxygen gases to the cell; (2) development of a high-out-put, lightweight cell; and (3) a high capacity, lightweight battery.

2494
Dietz, D. FUEL CELLS - ALMOST HERE. Mat. Handling Eng. 15:50-53, Jly. 1960.

Discusses fuel cells in general; ZnO cells, fuel gas cells, C cells, hydrox cells, carbox cells, sodium amalgam cells and redox cells in particular.

2495
DIRECT GENERATION OF ELECTRICAL ENERGY BY MEANS OF ELECTROCHEMICAL FUEL CELLS. Ing. 66:85-91, Aug. 20, 1954.

Considers the efficiencies obtainable with a primary cell, utilizing the reaction of a gaseous or solid fuel with oxygen, in relation to change in entropy determined by change in number of gas molecules. Discusses Davtyan and other recently invented cells, with performance data. Shows that combination of fuel cells and water-gas generator, proposed by Forin, offers no increase in electrical energy produced.

2496
Douglas, D. L. ADVANCES IN FUEL CELLS. Am. Soc. Nav. Engrs. J. 72:271-275, 1960.

Outline of basic principles of fuel cells and discussion of present position and possible future development.

2497
Eerkens, J. W., and Reder, M. C. CLOSED-CYCLE MONOPROPELLANT FUEL CELL SYSTEM EMPLOYING RADIATION-GENERATED OR PHOTOCHEMICALLY GENERATED OZONE. Paper presented at the ARS Space Power Systems Conference, Santa-Monica, Calif., Sept. 27-30, 1960. n.p. New York, American Rocket Society, 1960. (Paper 1306-60)

A new photochemical/nuclear energy conversion system is described which is based on the following conversion steps. Kinetic energy of photons or nuclear particles is transferred into chemical energy of recombination through the exposure of oxygen to sunlight in the exosphere or through irradiation of oxygen in a nuclear chemogenic reactor or isotopic irradiator, which causes oxygen to recombine to ozone after photolysis or radiolysis. The efficiency of this chemical energy storage process varies between 10 and 15%, depending on the operating conditions. The ozone (mixed with oxygen) is then passed over a specially treated porous electrode of a fuel cell, at which the ozone reacts with the electrolyte. At the other electrode of the cell, oxygen is liberated. The overall reaction is the formation of oxygen from ozone with the liberation of two 0.84 ev electrons. Preliminary studies indicate the overall feasibility of the system. For space applications a typical 100-watt unit employing radioactive Kr mixed with oxygen would weigh 130 lb, if beryllium is used for containment, or 160 lb if stainless steel is used. Total volume would be approximately 10 ft^3. Operating life would be approximately 10 years. (Astron. Info. Abs. 3:3208, 1961)

2498
Eisenberg, Morris. ELECTRO-CHEMICAL FUEL CELL FOR TRANSPORTATION. Soc. Automotive Engrs. Paper 212B for meeting August 16-19, 1960.

Desirability of employing fuel cells in electric automobiles; advantages of electric transportation; fundamental principles of electrochemical fuel cells; use of redox cells; it is found that as far as ground transportation in automotive applications is concerned, chemical fuel cells operating from inexpensive fuels are indicated; future research needed. (Eng. Index p. 506, 1960)

2499
ELECTRICITY FROM THE DECOMPOSITION OF ORGANIC MATTER. Discovery 22:228, June 1961.

Brief mention of a biochemical fuel cell developed by Dr. F. D. Sisler, a biochemist of the U.S. Geological Survey, which produces electricity directly from the decomposition of organic matter.

2500
Evans, G. E. ELECTROCHEMICAL ENERGY STORAGE FOR INTERMITTENT POWER SOURCES. 9p., New York, United Nations, Apr. 11, 1961. (E/CONF/35/GEN/3)

Preprint of paper prepared for United Nations Conference on New Sources of Energy.

Two types of electrochemical energy storage systems are considered: lead acid storage batteries and hydrogen-oxygen fuel cells in combination with water electrolyzers and gas storage tanks.

2501
Fick, L. and Eisenberg, Morris. FUEL CELL ANALYSIS. Chem. Eng. Prog. 57:74, fig., May 1961.

Comments on "Fuel Cells" by E. Gorin and H. L. Recht (Chem. Eng. Prog. 55, Aug. 1959) and corrects a possible misprint in the last term of the expression for V, as well as making a more precise evaluation of the expression for R_{eff}/R. Includes further comment by Gorin.

2502
FUEL CELL DRIVES A TRACTOR. Bus. Wk. p. 33-34, illus., Oct. 17, 1959.

Allis-Chalmers demonstrates a 20 kp model, stirring hopes for speedy commercial use of direct power from chemicals.

2503
"FUEL CELL" FOR PROPULSION: LOCKHEED MISSILE DEVELOPMENT. Financial Times p. 9, Nov. 18, 1958.

Report of announcement by D. M. Eisenberg, of Lockheed Missile Systems Division, that Lockheed has developed "fuel cell" able to produce ten times the energy of equally heavy car storage battery. He predicted that, in five years time, the cell would be used to power cars, aeroplanes, and space vehicles. Details and nature of materials were not disclosed. The battery achieved almost 100% fuel utilization and efficiency of at least 70%. (Fuel Cells Bib., Mond Nickel Co., 1960)

2504
FUEL CELL POTENTIAL GROWS. Petrol. Wk. 7:10, Nov. 21, 1958.

Brief news item regarding new claims for the potential of a fuel cell.

2505
FUEL CELL RESEARCH GETS ANOTHER BOOSTER. Prod. Eng. 29:10, Nov. 3, 1958.

Brief report of fuel cell development at Allis-Chalmers.

2506
FUEL CELL TRACTOR USES LOW COST PROPANE. Am. Gas. J. 186:24, 1959.

Details are given of a fuel cell system which powered a demonstration tractor.

2507
FUEL CELLS. New Scientist 4:395, Jly. 17, 1958.

Editorial reviewing work on Sondes Place Research Institute on Fuel cells. Town gas, paraffin, methanol, and other fuels are used to generate electricity. Basic cell consists of two electrodes with gas ducts separated by porous membrane containing $LiCO_3$. Battery of cells, to generate about 3 KW at 80 volts (d.c.), is to be constructed, with stainless steel electrodes. "Judging from the progress at Sondes Place, practical fuel cells will be with us as soon as the supply of money will allow. This year, the Ministry of Power is spending only £10,000 on the project." (Fuel Cells Bib., Mond Nickel Co., 1960)

2508
FUEL CELLS. Indus. Eng. Chem. 52:291-310, Apr. 1960.

Fuel cells, with their promise of attendant simplicity, efficiency, light weight, long life, and low upkeep are causing a spate of interest as they pass the point of technical feasibility and approach commercial utilization. These devices, not limited by the dictates of the Carnot cycle, are operating at efficiencies reportedly up to twice that of the best conventional systems. They are being developed in several different types based on aqueous and non-aqueous electrolytes and classified as direct or indirect (redox) cells. In the direct type, the fuel is consumed directly within the cell, whereas in the indirect or redox type the fuel and oxidant are used to regenerate chemically the anodic or cathodic reagents. Other classifications can be made based on the nature of the fuel: carbonaceous fuels versus hydrogen; or the oxidant, air versus oxygen; or based on the operating conditions such as temperature or pressure. In this review fuel cells are treated as electrochemical devices; catalysis of fuel cell electrode reactions are discussed and nature of electrode process is described. Explanation of carbonaceous fuel cells, hydrogen-oxygen fuel cells, and high-temperature fuel cells are given.

2509
FUEL CELLS. Power Eng. 65:67-71, Jan. 1961.

Principles, historical background, types and present applications are given.

2510
FUEL CELLS COME CLOSER TO COMMERCIAL UTILIZATION. Prod. Eng. 30:21, Jan. 3, 1959.

Work in progress, by several companies, on chemical-into-electrical energy-conversion devices is mentioned briefly.

2511
FUEL CELLS FOR THE FOOT-SOLDIER. Mach. Design 32:44, illus., May 12, 1960.

Includes an illustration of a fuel cell pack useable by the Army for powering portable radar sets.

2512
FUEL CELLS GENERATE POWER FOR EXPERIMENTAL TRACTOR. Design News 14:4, Nov. 9, 1959.

An experimental tractor, developed by the Research Division of Allis Chalmers Manufacturing Co., Milwaukee, Wis., uses fuel cells to supply electric current to its drive motor. Using propane and oxygen, the fuel cells generate up to 15 kw of power to run a 20-hp electric motor connected to the tractor drive train. During demonstration, it plowed a field for 17 minutes and used two pounds of fuel; it easily pulled a multiple-bottom plow.

2513
FUEL CELLS NEARER MARKET. Bus. Wk. p. 68, Sept. 19, 1959.

F. T. Bacon forecasts future of fuel cells for military applications in the near future and for civilian applications at a later date.

2514
FUEL CELLS, NEW POWER SOURCE. Soc. Automotive Engrs. J. 67:38-40, illus., Aug. 1959.

According to C. E. Larson and A. M. Moos, at a meeting of the SAE Aircraft Powerplant Activity Comittee, the process is much like that of the flashlight battery but new materials and methods make the fuel cell much more powerful and efficient.

2515
FUEL CELLS POINT WAY TO MORE EFFICIENT POWER GENERATION. Purchasing 48:64, 1960.

An experimental tractor is illustrated, the power for which is produced by fuel cells.

2516
FUEL CELLS PUSH AHEAD. Indus. Eng. Chem. 51:36A, 38-39A, illus., May 1959.

De Soto predicts cars can be driven by fuel cells; elsewhere research hums along, gets close to a practical cell.

2517
FUEL CELLS START ROLLING. Mach. Design 32:12, June 9, 1960.

Report of agreement signed between Electric Storage Battery Co. and material-handling equipment manufacturers, to stimulate mass-production of important fuel cells. Illustration of installation of Exide Zn-O fuel cell to power racing car.

2518
FUEL CELLS' THREAT GROWS. Petrol. Wk. 7:36, illus., Dec. 12, 1958.

Brief news note indicating that the fuel cell is now considered an extremely promising method for generation of power.

2519
FUEL CELLS USING A MIXTURE OF OXYGEN AND SODIUM OR HYDROGEN WILL SOON POWER A SUBMARINE. Chem. Wk. 88:45-46, Apr. 22, 1961.

"The Navy says it will convert a conventional diesel-fueled submarine to operate on fuel cells within two years. A land-based prototype will be built in the coming year. Long range, the Navy hopes to build a fleet of small attack submarines powered by fuel cells.

"The Navy makes it clear that submarines powered by fuel cells will augment, but not replace, the large fleet of nuclear-powered submarines now planned. The Navy doesn't plan to convert existing conventionally powered subs to fuel cell propulsion.

"The Navy says that with fuel cells it can get an 80% efficiency ratio compared with only about 40% from nuclear or conventional power. Other advantages: the cells extend the underwater operation period of a submarine to a matter of weeks, instead of the two or three days typical of conventional submarines. Fuel cell-powered vessels, too, will be cheaper and quieter than nuclear-powered submarines.

"Currently, the Navy is thinking of using fuel cell power for a fleet of submarines only one-half to one-third the size of NAUTILUS-class nuclear boats. Costs would be reduced on the same order." Entire item quoted.

2520
FUEL CELLS WITH AN EFFICIENCY OF 70 TO 80%. Prod. Eng. 29: 18, Feb. 17, 1958.

Fuel cells with 70-80% efficiency, being developed by Patterson-Moos Division, Universal Winding Co., are H-O cells using Ni electrodes and KON electrolyte. One model weighs less than 100 lbs and will operate for 6 hours at rated capacity of 1.5 KW.

2521
GASEOUS FUEL CELL HAS HIGH EFFICIENCY. Electron. 31:116, 118, Oct. 24, 1958.

Brief announcement of operation of a device which illuminated two 15-watt light bulbs by the energy from a cell.

2522
GASEOUS FUEL CELL PROVIDES ELECTRIC POWER. Elec. Eng. 78:195-196, Feb. 1959.

Report of an experimental development of a gaseous fuel cell which was successful in lighting two 15-watt electric light bulbs.

2523
General Electric Co., West Lynn, Mass. RESEARCH ON LOW TEMPERATURE FUEL CELL SYSTEMS. 3 issues, Oct. Dec. 1960, Feb. 1961. (Prog. Repts. 13, 14, 15) (Contract DA44-009-eng-3771) (AD-252 833, AD-256 939, AD-260 739)

Continuing work is reported in the testing of new cell structures.

2524
Gorin, Everett and Recht, H. L. FUEL CELLS. In Battery Research and Development Conference, Proceedings, 10th, p. 53-56, Fort Monmouth, N. J. 1956.

Review of progress for the past ten years.

2525
Gurevich, I. G. THE PRESENT-DAY SITUATION IN THE FUEL CELL DEVELOPMENT FIELD. Inzhen. Fiz. Zhurn. 1:75-88, 1958.

In Russian. Trans. by Aerospace Technical Intelligence Center, Wright-Patterson AFB, no. MCL-403. (AD-255 377) Available from OTS. Also Trans 59-17423 available from LC or SLA.

A review is made of the development of fuel cells as noted in publications of the last decade. The theory of the fuel cell is discussed as well as the types (direct and indirect, and oxidation-reduction), materials, and the prospects of application.

2526
Hunger, H. F. ION EXCHANGE LIQUID FUEL CELLS. In Power Sources Conference. Proceedings, 14th, p. 55-59, Red Bank, N. J., PSC Publications Committee 1960.

A new fuel cell, investigated at the U.S. Army Signal Research and Development Laboratory, is described. The cell operates on alcohol and oxygen or air, utilizing an ion exchange membrane as the electrolyte.

2527
Justi, Eduard. THE ECONOMIC GENERATION AND STORAGE OF ELECTRICITY BY USE OF FUEL CELLS. ETZ. 13B:377-386, Jly. 10, 1961.

In German. Fuel cells are galvanic cells which convert the chemical energy from the oxidation of commercial fuels directly into electrical energy at high efficiency. The idea of avoiding in this manner the detour via the heat engine, which in accordance with the second law of thermodynamics involves unavoidable losses, was put forward as early as 1894 by Wilhelm Ostwald, but in spite of efforts spread over many years by such famous workers as Nernst and Haber, no success was achieved. Recently this work has again been taken up, and considerable initial success has been achieved by using suitable gaseous or liquid fuels, in particular hydrogen and alcohols. Cells fed with H_2 and O_2 give efficiencies up to about 90% at low current densities; the loading per square centimetre of electrode surface, which is over 500 mA/cm^2, exceeds that of all other known batteries, and then an efficiency of over 50% can still be obtained. For engineering purposes the high energy density per unit volume and unit weight is particularly important. These cells can also be used with advantage for the reverse process of the electrolytic decomposition of water. The combination of these processes should give economic energy storage by the electrolysis of water with excess current, storage of the compressed

gases from electrolysis, and their recombination to generate current in the oxygen-hydrogen element in case of peak power demand. Special elements operate with liquid fuels and should in the future become of interest for driving vehicles.

2528
Justi, Eduard, Bischoff, Kurt, and Spangler, Herbert. STATE AND PROSPECTS FOR REVERSIBLE GENERATION OF ELECTRICAL ENERGY FROM SOLID FUELS IN FUEL ELEMENTS WITH SOLID ELECTROLYTES. In Akademie der Wissenschaften u. der Literatur, Abhandlunger der Mathematisch-Naturwissenschaftlicken Klasse no. 1 p. 3-26, 1956.

In German. Discusses electrochemical generation of energy. The authors have succeeded in building a direct fuel element with solid electrolytes, that attained 99% of the theoretical emf at an operating temperature of 750°C and possessed a life span of several months with load.

Trans, no. E-409 available from RIS Div. Pergamon International Corp., New York, N. Y., also Trans. 619-GJ available from Associated Technical Services, Inc., East Orange, N. J.

2529
Kangro, Walther. DIE UNMITTELBARE GEWINNUNG VON ELEKTRIZITAET AUS BRENNSTOFFEN. (PRINCIPLES AND POTENTIALITIES OF THE FUEL CELL). Motortech. 22:11-17, Jan. 1961.

In German. Problems involved in developing a practical device are discussed, and Justi's high-power hydrogen-diffusion electrode for operation in ambient temperature and low pressure is studied. The extensive development work conducted in the U.S. and Great Britain is reviewed. (Inter. Aerospace Abs. 1:61-5227, Jly. 1961)

2530
Kaprielyan, S. P. PERSPECTIVE ON DIRECT POWER CONVERSION. Aircraft & Missiles 3:22-24, May 1960.

The development of useful fuel cells for electric power generation again hinges upon extensive materials research. Additional information is needed on the physical and chemical properties of fused salts.

2531
Ketalaar, J. A. A. and Broers, G. H. J. FUEL CELLS. TNO Nieuws (Holland) 9:39-41, 1954.

A modified Davtyan cell gave more than 5 amp. per sq. dm. of effective electrolyte surface, with power 2 w. per sq. dm. At working temperature, 700-800°C, "solid" electrolyte is actually liquid phase held by porous solid. (Fuel Cells Bib., Mond Nickel Co., 1960)

2532
Kirkland, T. G. THE FUEL CELL POWERED TRACTOR. In American Power Conference. Proceedings, March 29-31, 1960, Chicago, Ill., vl. 22, p. 465-469, Chicago, Illinois Institute of Technology Press, 1960.

History of research on fuel cells at Allis-Chalmers is reviewed, followed by a description of the cell unit, the power plant for the tractor, details of tractor operation, and future work planned. A final paragraph suggests various applications for fuel cells.

2533
Liebsafsky, H. A. and Niedrach, L. W. FUEL CELLS. Frank Inst. J. 269:257-267, 1960.

A general discussion of fuel cells points out the great current interest in them and outlines the requirements they must meet. The status of representative fuel cells for special applications is indicated, and the ion-exchange membrane cell is discussed.

2534
Lozier, G. S. FUEL CELLS AND BATTERIES. RCA Rev. 22:325-346, figs., June 1961.

This paper discusses the present state of development of fuel cells and batteries as energy sources and energy-storage devices. The various types discussed are evaluated from a consideration of the energy content of the reactant materials and the basic methods of handling the reactant materials in electrochemical cells. Regenerative electrochemical cells are also discussed, with emphasis on space applications.

Also in Engrs. Dig. 22:74-79, 119. Sept. 1961.

2535
Lynch, C. J. WHAT USE FOR THESE UNCONVENTIONAL POWER SOURCES? Prod. Eng. 32:57-59, illus., Jly. 10, 1961.

Eight laboratory curiosities for generating power are briefly described, among them the organic fuel cell.

2536
McGraw, L. D. ADVANCES IN BATTERY-POWER SYSTEMS. Battelle Tech. Rev. 7:8-12, Nov. 1958.

Review covering interalia, fuel cells and solar converters, nuclear cells, new electrochemical systems (solid-electrolyte battery, ion-exchange cells), new depolariser materials, Ni-Cd (alkaline) and Ag-Zn batteries.

2537
McGraw, L. D. FUEL CELLS: INTRODUCTION. 9p; New York, Society of Automotive Engineers, 1960 (Rept. 179A)

Paper presented at SAE summer meeting, June 1960.

The technical and economic aspects of battery power sources are explained and an elementary aid is given to recognizing advances in research towards a practical fuel cell. Fuel cells as specialized batteries, fuel cell efficiency and kinetics, regenerative fuel cells, and fuel costs are discussed.

2538
Magram, S. J. and Stein, B. R. ARMY FUEL CELL PROJECTS. Soc. Automotive Engrs. J. 68:27-28, June 1960.

This article is based on a paper (Rept. 179B) given at the SAE summer meeting.

Projects, numbering more than 20, are briefly outlined. They form a balanced program aimed to uncover successful applications for the future.

2539
Michael, G. FUEL CELLS GET TRYOUT. Plant & Power Services Engr. 2:14-15, Jan. 1960.

Like other electric cells, fuel cells consist of electrodes, electrolyte, and produce d-c power, but unlike batteries they cannot store energy. Fuel such as H_2, natural gas, or gasoline is chemically reacted with O_2, and current is caused to flow between electrodes of system. Tractor developed by Allis-Chalmers produces 15 kw and drives 20 hp motor from 1008 individual cells joined in 112 units of 9 cells each; vehicle has draw-bar pull of 3000 lb. (Eng. Index p. 507, 1960)

2540
Micka, Karel. PROGRESS IN THE DEVELOPMENT OF FUEL CELLS. Chem. Listy 55:129-138, 1961.

A review with 13 references.

2541
Miller, K. D. SODIUM FUEL CELL GOES OPERATIONAL. Chem. Eng. Prog. 57:140, 142, figs., Feb. 1961.

Full-scale chemical power plant under development for U.S. Navy will use sodium amalgam-oxygen combination.

2542
NAVY TO DEVELOP SUBS POWERED BY FUEL CELLS. Prod. Eng. 32:12, Apr. 24, 1961.

"The Navy will convert a conventionally powered submarine to operate from fuel cells within the next two years. This year, it will start building a land-based prototype. Long range, the Navy may build an entire fleet of small attack submarines powered by fuel cells.

"Navy says it can obtain an 80% efficiency ratio now with cells fueled by oxygen and sodium or hydrogen. Conventional and nuclear-powered submarines only obtain about a 40% efficiency ratio.

"Though it's admittedly in the research state, some Navy engineers see fuel-cell development as rivaling the harnessing of nuclear power. And they envision more uses outside the submarine field than within it - such things, for example, as power for automobiles may eventually prove feasible.

"Fuel cell-powered subs would augment, but not replace, nuclear-powered subs. Navy doesn't plan on converting more than one conventional submarine. Advantages of the new power unit shape up like this:

"It increases the underwater endurance of conventional subs to several weeks instead of 2 to 3 days; cost of fuel-cell-powered submarines is estimated at only 1/2 to 1/3 that of nuclear-powered submarines; because they are quieter to operate than the nuclear subs, they are less vulnerable to enemy detection; they can be built smaller.

"For a long time, Navy has wanted to build a small attack submarine about 1/3 the size of its standard nuclear sub. Size and cost of a nuclear powerplant, however, has prevented this. Fuel cells may be the answer, one Navy source says.

"It will likely be three to four years, however, before final decisions are made. And, Navy emphasizes that its program is still in the R&D state." Entire item quoted.

2543
A NEW BATTERY: THE FUEL CELL: WILL IT HAVE AN IMPACT ON MINING? Eng. & Mining J. 159:89-91, May 1958.

Description of National Carbon Co. (Union Carbide Co.) fuel cell. Notes are given on fuel gas (with unspecified catalyst) and direct fuel cell (both illustrated). Short description of Redox fuel cell. Catalysts which will improve performance of air-H_2 cell are Pd impregnated on H_2-electrode, and Ag-Ag oxide on O_2-electrode.

2544
NEW FUEL CELL PROMISES HIGHER VOLTAGES. Eng. 191: 268, Feb. 17, 1961.

An improved fuel cell, which makes use of the electrical properties of the element sodium, has been developed. Its voltage output is double that of the hydrogen-oxygen cell.

2545
Nowacki, Pawel, Gorski, Andrzej, and Nalecz, Maciej. FUEL CELLS. Rozpr. Elektrotech. 4:53-67, 1958.

In Polish. Discussion of operation of fuel cells from viewpoint of reduction and oxidation processes occurring in these cells. Authors present a classification of fuel cells and possibility of constructing new types of cells resulting from this classification.

2546
Price, R. B. W. THE FUEL CELL. Birmingham Univ. Chem. Engr. 8:20-28, Oct. 1956.

Thesis digest covering practical fuel cell and its limitations; development of fuel cell; Davtyan, Redox, and Bacon cells. (Fuel Cell Bib., Mond Nickel Co., 1960)

2547
PROFIT POTENTIAL SPARKS FUEL CELL SCRAMBLE. Chem. Wk. 85:45-49, Jly. 1959.

Military interest in fuel cells has sparked a number of all-out development projects that are rapidly bringing these 150-year-old scientific oddities to the threshold of commercial application. Several fuel-cell systems, hydrogen-oxygen, molten-salt, redox, regenerative, consumable-electrode, and ion-exchange promise profitable application in power generating plants, ranging from large central stations to portable units and suitcase-size automotive power systems.

2548
Roberts, Ralph. THE FUEL CELL ROUND TABLE. Electrochem. Soc. J. 105:428-432, 1958.

A round-table discussion of fuel cells was held on October 10, 1957, as part of the Battery Division program of the 112th Meeting of the Electro-Chemical Society in Buffalo, N. Y. The discussion was organized by G. Heise, National Carbon Laboratories (retired), who also acted as panel chairman. Roberts presents a digest of the topics discussed at the round-table.

2549
Rosenberg, R. B. FUEL CELL RESEARCH AND ITS SIGNIFICANCE TO THE GAS INDUSTRY; SPECIAL REPORT. Am. Gas J. 186:17-23, 1959.

A comprehensive report on direct chemical-to-electrical energy conversion, who's doing what, and what it means to the gas industry.

2550
Rosenberg, R. B. SIGNIFICANCE OF FUEL CELL RESEARCH TO GAS INDUSTRY. In American Gas Association, Operating Section, 1959, Proceedings...p. P213-219. New York, The Association, 1959. (Paper CEP-59-20.)
Principles and development of apparatus for converting chemical energy into work by causing combustion reaction to proceed in two ionic steps. Advantages and disadvantages of ambient-temperature indirect, high-temperature indirect, redox, natural gas, hydrocarbon-carbon monoxide mixtures, process hydrogen and pure hydrogen cells. Based on future technical advances, application in gas industry is feasible. (Eng. Index p. 507, 1960)

2551
Ruka, R. J. FUEL CELLS. Power Eng. 65:67-71, Jan. 1961.

Principles, historical background, types, and present applications are discussed.

2552
SCIENTISTS INVESTIGATE ECONOMICS OF FUEL CELLS. Chem. & Eng. News 39:86, 88, Sept. 18, 1961.

Brief mention is made of reports given at the Symposium on Fuel Cells at the September 1961 meeting of the American Chemical Society by Dr. C. G. von Fredersdorff, Dr. C. E. Heath and Dr. C. H. Worsham.

2553
SEAGOING FUEL-CELL POWER AT PROTOTYPE DESIGN STAGE. Indus. Sci. & Eng. 8:26-27, Jan. 1961.

One of the first major applications of the fuel cell principle to specific power and service requirements is represented in a $764,000 contract awarded by the Navy Bureau of Ships to the M. W. Kellogg Company. Based on the success of two earlier research programs by the firm, the new development project calls for the design and testing of a complete chemical power plant, a prototype of a Naval version for use by that service. (Fuel Bas. & Current Titles 2:4359, Jly. 1961)

2554
SEAWATER-BACTERIA BATTERY. Missiles & Rockets 8:23, Apr. 24, 1961.

"There are unconfirmed reports that a method has been found to extract energy from the ocean by use of an "oceanic battery" composed of iron cathode coated with bacteria and magnesium anode. The battery gets energy from naturally occurring ions in some ocean solids -- nitrates, carbohydrates, sulphates, and others. Power output is said to be five times that of ordinary magnesium types." Entire item quoted.

2555
SHELL'S LOW TEMPERATURE FUEL CELL. Petrol. 23:391, Oct. 1960.

Announces that the cell generates from three to five times more power per unit volume than other similar cells under development. (Battelle Tech. Rev. 10:63h, Jan. 1961)

2556
SHORT CUT TO ELECTRICAL ENERGY Bus. Wk. p. 37, 38. Dec. 6, 1958.

Report on Lockheed Aircraft Corp. development of fuel cell for conversion of chemical into electric energy at 70% efficiency.

2557
Shultz, E. B., Jr., et al. FROM FUEL CELL, POWER FOR HOMES? Am. Gas. Assoc. Mon. 43:11-12, 31-32. May 1961.

Current progress of an Institute of Gas Technology project is reviewed as well as that on related engineering economic studies, which are directed primarily toward the development of fuel cell power packs for dwellings, to supply all or most of the home needs for electricity.

2558
SODIUM REACTION POWERS NEW FUEL CELL. Oil & Gas J. 58:84, Dec. 26, 1960.

A new kind of fuel cell, one that uses an amalgam of sodium in mercury and oxygen to produce electricity, has been revealed by the M. W. Kellogg Co. The sodium-mercury cell's efficiency is 60%, high when compared with such other fuel cells as the Hydrox or the Carbox. Westinghouse, in the meantime, has revealed an entirely new concept in power conversion. The company has found that certain combinations of ceramics and metals can produce electricity when they are heated. In the first test, the combination was a piece of iron coated with ordinary vitreous enamel, which in turn had a thin silver covering. At temperatures between 400 and 1400°F, the combination produced power -- at a rate of 16 mW/in^2 of the silvered surface. (Fuel Abs. & Current Titles 2:2346, Apr. 1961)

Also in Bus. Wk. no. 1634:35-36, Dec. 24, 1960.

2559
Straatman, J. F. NEW TYPES OF GALVANIC FUEL CELLS. Brit. Chem. Eng. 4:286-288, 1959.

History of fuel cell development, with descriptions of the Davtyan, De Broer, and National Carbon Co. cells. (Fuel Cells Bib., Mond Nickel Co., 1960)

2560
Tantram, A. D. S. FUEL CELL PROGRESS, THE LAST YEAR AND THE FUTURE. Fuel Effic. 9:50-51, Feb. 1961.

A brief review is given of the rapidly rising interest now shown in fuel cells both in Great Britain and in the United States. (Fuel Abs. & Current Titles 2:2938, 1961)

2561
Thring, M. W. DIRECT PROCESSES FOR GENERATING ELECTRIC POWER. New Scientist 6:522-524, 1959.

Theoretical discussion of electromagnetic and electrostatic electricity generators, which use hot combustion gases as fuel. It is stated,

in discussion of fuel cells, which is known to be ideal method of generating electricity from fuel, that no really practical fuel cell has been found so far.

2562
TRACTOR POWERED BY 1008 FUEL CELLS. Agr. Eng. 40:684-687, 1959.

Note on experimental unit developed by Allis-Chalmers Mfg. Co., which develops at least 3000 lbs of drawbar pull. Chemical reactions within cells produce 15 kw of electricity. A direct current goes through busbars to compact controller which regulates speed and direction of tractor by controlling amount of current reaching 20-hp motor.

2563
Trudeau, A. G. ARMY RESEARCH AND DEVELOPMENT PROGRESS. Signal 15:4-6, Jly. 1961.

New energy sources are mentioned and the importance of the fuel cell is stressed. A possible solution to the age-old logistics problem is forecast by the integration of the fuel cell--or groups of cells--with the nuclear reactor.

2564
Watson, R. G. H. ELECTROCHEMICAL GENERATION OF ELECTRICITY. Res. 7:34-40, 1954.

Progress made in construction of fuel cells to date and future developments discussed. Types of fuel cell available, performance and limitations of fuel cells. Materials used in construction of fuel cells, including reference to use of porous C activated with metallic Ni as used in Davtyan low-temperature cell which is sheathed in Ni-plated steel sheet.

2565
Watson, R. G. H. FUEL CELLS. Inst. Heat. Vent. Engrs. J. 22:120-121, 1954.

Discusses: (1) H-O cells; (2) a high temperature cell operating at atmospheric pressure, 700-800°C using industrially available gases, e.g., CO; and (3) low-temperature cell using oxidation-reduction system involving oxidizing properties of the air separately to chemical carrier outside cell, and interaction of the reducing and oxidizing carriers inside cell.

2566
Weissbart, Joseph and Ruka, R. FUEL CELLS. Westinghouse Engr. 20:108-110, Jly. 1960.

Fuel cells offer the possibility of more efficient conversion of chemical to electrical energy than conventional electric power generation methods. An ideal fuel cell would use cheap fuels, be made of economical materials, operate at high efficiency, have high power output per unit volume and weight of cell, and a long life. It appears that the low-temperature cells should begin to find special purpose applications within the next few years. The use of fuel cells for large-scale power generation is still in question and will require either a drastic reduction in fuel and capital costs or a low-temperature cell to utilize low-cost fossil fuels.

2567
Weissbart, Joseph. FUEL CELLS - ELECTROCHEMICAL CONVERTERS OF CHEMICAL TO ELECTRICAL ENERGY. J. Chem. Ed. 38:267-272, May 1961.

Principles of operation, history of development, thermodynamic considerations kinetic considerations and types, e.g. hydrogen-oxygen (KOH), hydrogen-oxygen ion exchange membrane cells, molten salt (carbonate) cells, and solid electrolyte (ceramic oxide) fuel cells.

2568
White, D. C. and Riaz, Mahmoud. ELECTROCHEMICAL ENERGY CONVERSION PRINCIPLES AND PRACTICES. In Seminar on Advanced Energy Sources, 1958. Proceedings...p. 181-202, Fort

Monmouth, N. J., 1959? (Contract DA36-039-78064) (PB 151461) (AD 209301)

As illustration of the kinds of problems encountered in electromechanical conversion systems, airborne constant-frequency parallel generating systems are considered. The potentialities of some new configurations of electromechanical energy converters are explored for possible future applications.

2569
Williams, K. R. MAKING FUEL CELLS MORE COMPETITIVE. Eng. 192:342-343, illus., Sept. 15, 1961.

With their high efficiencies, fuel cells already compete with conventional engines where first cost is immaterial. The author believes that research will produce cells for the commercial market.

2570
Witkin, Richard. BATTERY WITH BACTERIA CATALYST COULD USE SEA MATTER AS FUEL. New York Times p. 1, 20, Oct. 25, 1961.

It is indicated that the potential advantage of such power units as the "bio-battery" developed in Magna Products, Inc. laboratories, is that through the catalytic help of bacteria, or enzymes, electricity could be produced from a wide variety of fuels and oxidants that are now unusable. A bio-solar cell is also a possibility. The latter would generate its fuel supply to power space ships.

Several companies engaged in the bacteria battery research are mentioned, along with the advances in power levels achieved.

2571
ZINC-TYPE FUEL CELL NEARS APPLICATION IN INDUSTRIAL TRUCKS. Prod. Eng. 31:17, May 30, 1960.

Within three years, Exide Industrial Division of Electric Storage Battery Co. expects to have a fuel cell of unusually simple design operating in electric industrial trucks. This cell, now past basic- and applied-research stages, uses zinc as fuel and compressed oxygen for oxidizer.

2. Theory

2572
Chanu, Jacques. POTENTIAL THERMOELECTRIQUE STATIONNAIRE DANS LES SOLUTIONS IONIQUES EN EQUILIBRE SORET. (THE STATIONARY THERMOELECTRIC POTENTIALS IN IONIC SOLUTIONS IN SORET EQUILIBRIUM). Acad. Sci. Paris. Compt. Rend. 243:239-241, Jly. 16, 1956.

In French. Using the thermodynamics of irreversible processes, based on reciprocal relations of Onsager, Chanu reports on the thermal diffusion ionic solutions. His data indicate a phenomenological relation among the electrical potential gradient and the gradients of concentration and temperature. Experimental results and theory are compared.

2573
Daniel'bek, V. S., Mints, M. Z., et al. STUDY OF FUEL CELLS WITH SOLID ELECTROLYTES. In Trudy Chetvertogo Soveshchaniya po Elektrokhimii (Conference on Electrochemistry), 1-6 October 1956, p. 794-800, 1959.

In Russian. Trans. by Aerospace Technical Intelligence Center, Wright-Patterson AFB, no. MCL-402, (AD-255 376) available from OTS. Trans. R. J.-2694 also available from Associated Technical Services, Inc., East Orange, N. J.

Results are given of investigations in the field of fuel cells with solid electrolytes and intended for operation at high temperatures. Thermodynamic calculations of the theoretical values of the maximum efficiency and emf of high temperature fuel cells with coal, CO, and

H_2 were repeated. New data were added concerning the free energy and heat content of H_2O, CO_2, and CO. These results confirmed that fuel cells operating on coal or a gas-like fuel from 500 to 1000 degrees can theoretically have high efficiency (up to 100%) with an emf close to 1 volt.

2574
Liebhafsky, H. A. THE FUEL CELL AND THE CARNOT CYCLE. Electrochem. Soc. J. 106:1068-1071, Dec. 1959.

To provide a basis for considering the combination of nuclear reactor (or other heat source) and fuel cell, the well-known fact that the fuel cell escapes the Carnot-cycle limitation is reviewed briefly. Then it is shown that the combination cannot escape this limitation, and, in some cases, can only approach the Carnot-cycle efficiency.

2575
MEMBRANE REPLACES FUEL-CELL ELECTROLYTE. Chem. Eng. 66: 62, Aug. 10, 1959.

Brief mention of an ion exchange membrane which, acting as a solid electrolyte, makes possible a very compact structure for a fuel cell.

2576
Pchenichnikov, A. G. TRANSFORMATION OF THE CHEMICAL ENERGY OF FUEL INTO ELECTRICAL ENERGY IN FUEL CELLS. Teploenergetika 3:47-51, 1956. (no. 10)

In Russian. Rough draft trans. available MCL-401/1. Order from LC or SLA, no. 61-19402.

A survey.

2577
Strocchi, P. M. and Foraboschi, F. P. STUDIO TERMODIAMICO DELLE PILE A COMBUSTIBLE (THERMODYNAMIC STUDY OF FUEL CELLS). Termotecnica 12:273-280, 1958.

In Italian. Presents a thermodynamic study of fuel cells; calculations of reversible emf, relative to oxidation of principal types of fuel at various temperatures and pressures; and the ratio of variations of Gibbs free energy to reversible emf, which also represents maximum thermodynamic limit obtainable, theoretically and in practical realization of fuel cells.

3. Electrode Processes

2578
Anthony, P. P. CATALYSIS FOR THE ELECTROMOTIVE ACTIVATION OF CARBON MONOXIDE AND HYDROGEN IN ALKALINE MEDIA AT THE ANODE OF A FUEL CELL. Univ. Microfilms Pub. 1957, 159p. (L. C. Card Mic 58-2053)

Dissertation presented to Ohio State University. Study of catalysis of electrochemical reactions of Co and H in alkaline solution of various metals. Catalysts tested with CO included Pd, Pt, Rh, Ru, Os, Ni carbonyl and various metal oxides. Catalysts tested with H included Pt, Pd, Rh, and mixed oxides, including Ni, Co and Fe oxides. Details of incorporation of catalysts in electrodes. Work in connection with fuel cells: electrodes which were used as anodes in a voltaic cell combined with an air of electrode, plated with Pd, or of similar construction to anode as cathode. (Fuel Cells, Bib., Mond Nickel Co., 1960)

2579
Brooklyn Polytechnic Institute, Brooklyn, N. Y. FUEL CELL AND ITS RELATED TECHNOLOGY. I. CORRELATION BETWEEN MAGNETIC SUSCEPTIBILITY AND CATALYTIC ACTIVITY OF ELECTRODES. II. CORRELATION BETWEEN INFRARED SPECTRUM AND CATALYTIC ACTIVITY OF ELECTRODES. III. CORRELATION BETWEEN SURFACE CONDUCTIVITY AND CATALYTIC ACTIVITY OF ELECTRODES,

Bimonthly Progress Report, by J. C. Chu et al. 12 issues, 1960, 1961. (Fuel Cell Reports 1 through 12) (Contract DA44-009-eng-4586) (AD-252 101 through 109, AD-255 732 through 734)

Main effort was given to the design of an electrode sample which could furnish satisfactory data for both emf and magnetic susceptibility. Three best devices for measuring magnetic susceptibility are presented.

2580
California Research Corp., Richmond, Va. INVESTIGATIVE STUDY RELATING TO FUEL CELL. 2 issues, Jly. 1960, Mar. 1961. (Quart. Prog. Repts. 1, 3) (Contract DA49-186-502-ORD-929) (AD-243 550, AD-254 312)

An investigation is being undertaken of the detailed chemical reaction mechanisms and kinetics of fuel half cell electrodes. The study will include: (1) development of chemical intermediates in an operating fuel cell by representative hydrocarbon-type fuels such as methylcyclohexane, cyclohexane, decalin, n-heptane, isooctane, hexene-1, a cyclopentane, and an aromatic; (2) the extent of the effects of electrolyte pH on the intermediates; (3) the polarization characteristics of an operating cell or fuel half cell; and (4) the details of the reaction between fuels and typical catalytic surfaces, such as Ni, Pd, and Pt with emphasis of the determination of the number of labile H atoms on the catalyst surface.

2581
Conway, B. E. FUNDAMENTAL BATTERY RESEARCH NEEDED. Elec. World 155:61-63, Feb. 13, 1961.

A general review of battery types is presented with the conclusion that more fundamental work is required on battery electrode systems to give a rational basis for improvement of operating power output, minimization of irreversibility, and improvement of cycle life and shelf or open-circuit lifetime.

2582
Diamond Ordnance Fuze Laboratories, Washington, D. C. CHARACTERISTICS OF OXYGEN ELECTRODES FOR LOW-TEMPERATURE FUEL CELLS by I. A. Denison. 12p., illus., Apr. 24, 1961 (Tech. Rept. 923)

Available information has been assembled and evaluated on the methods of preparation and the physical and electrochemical characteristics of oxygen electrodes for low-temperature fuel cells. Porous carbon and sintered metal cathodes have been considered with reference to methods of preparation, mode of operation, electrochemical characteristics, and other properties. Such electrodes are capable of operation in strongly alkaline electrolytes at current densities of several hundred amperes per square foot for extended periods of time. Electrodes of noble metals, such as platinized platinum, are used in fuel cells in combination with an acidic or alkaline ion-exchange membrane electrolyte. Because of the slowness with which hydrogen peroxide is decomposed in acid media, fuel cells with acid electrolytes do not ordinarily operate at current densities greater than 20 amp/ft^2.

2583
Elmore, G. V. and Tanner, H. A. INTERMEDIATE TEMPERATURE FUEL CELLS. Electrochem. Soc. J. 108:669-671, figs., Jly. 1961.

Gas fuel cells are described which utilize aqueous electrolytes and operate at atmospheric pressure at over 100°C. Under these conditions the product water escapes as vapor, thus avoiding dilution of the electrolyte and flooding of the electrode pores. Both acid and alkaline electrolyte compositions have been employed. The electrolyte contains a solid phase which reduces creep, and the electrodes are made nonwetting by the use of Teflon. Current densities of 50 - 100 ma/cm^2 have been realized.

2584
Engelhard Industries, Inc., East Newark, N. J. FUEL CELL CATALYSTS, by A. P. Hauel. 3 issues, Sept. 30, Dec. 31, 1960, Mar. 31, 1961. (Quart. Repts. 1, 2, 3) (Contract DA36-039-sc-85043) (AD-254 010, AD-254 011, AD-261 342)

A number of precious metals and combinations of precious metals deposited on carbon powder have been examined as catalysts for the oxygen electrode in sulfuric acid. Platinum on carbon appears to be the most active catalyst, the efficiency increasing with increasing platinum content. Further studies have shown that efficient catalysts can be prepared of both platinum black and of carbon-carrier-based catalysts.

2585
Eyraud, C., Lenoir, J., and Gery, M. FUEL CELLS UTILIZING THE ELECTROCHEMICAL PROPERTIES OF ADSORBANTS. Acad. Sci. Paris. Compt. Rend. 252:1599-1600, Mar. 1961.

In French. The three basic factors limiting the development of fuel cells are: the energy output, the specific power and the working temperature. With regard to the specific power, considerable advances may be achieved by, on the one hand, replacing the liquid electrolyte with a mobile adsorbed phase and, on the other hand, by passing a microporous cell element through the gaseous mixture of combustant and fuel. (Fuel Abs. & Current Titles 2:4355, Jly. 1961)

2586
Great Britain. Atomic Energy Research Establishment, Harwell. SOME EXPERIMENTS ON GALVANIC CELLS USING SOLID ELECTROLYTES, by G. W. Horsley. 24 p., Jan. 1961. (Rept. R-3427)

Variation of the emf with temperature of a number of solid electrolyte galvanic cells were measured and satisfactory results obtained on several.

2587
Gregor, H. P., Leonia, N. J. FUEL CELL MATERIALS. 2 issues, Nov. 30, 1960, Feb. 28, 1961. (Quart. Prog. Repts. 1, 2) (Contract DA36-039-sc-85384)

An improved cell for the measurement of the ohmic resistance of fuel cell electrolytes was designed. Work is being carried forward on improved homogeneous and heterogeneous type membranes; these will have catalyst incorporated into their faces. Cells for measuring the functional behavior of membranes in mixtures of organic liquid fuels and water were designed and are under construction.

2588
McCallum, John and Ditmars, W. E. ALKALINE PRIMARY CELLS HAVING ANODES OF NIOBIUM, VANADIUM, OR MOLYBDENUM. U.S. Patent 2,986,592 (To Remington Arms Co.), Jly. 17, 1956.

In a current-generating primary cell comprising a cathode, an anode, and an alkaline electrolyte, the improvement wherein said anode consists essentially of a material selected from the group consisting of niobium, vanadium, and molybdenum. (U.S. Pat. Off. Off. Gaz. 766:1321, May 30, 1961)

2589
RESEARCH ON ELECTRODE SYSTEMS. Chem. Age 84:879, 1960

Note on basic research on electrode systems at new laboratories of Chloride Electrical Storage Co., near Manchester. System using Ag oxide and Zn electrodes with KOH electrolyte can give five times output, in relation to volume and weight, compared with Ni-Cd alkaline system, but has disadvantages. Improvement of alkaline Ni-Cd batteries is being studied. Research on fuel cells includes work on porous electrodes which ionise O_2 and any fuel gases which can be

effectively oxidized (H_2 is present fuel).

2590
Speer Carbon Co. Research Laboratory, Niagara Falls, N. Y. DEVELOPMENT OF ELECTRODE MATERIALS FOR FUEL CELLS, by W. E. Parker et al. 2 issues Dec. 1960, Mar. 1961. (Repts. 2, 3) (Contract DA36-039-sc-85356) (AD-254 459, AD-260 120)

Samples have been prepared from a variety of raw materials and also a variety of fabricating conditions. A filler made from coconut shells has shown considerable promise. Activated carbons are also being tested. A study of the effect of process variables on the physical properties of carbons has been intensified.

2591
Western Reserve University. Ultrasonics and Electrochemistry Research Laboratory, Cleveland, Ohio. THE OXYGEN ELECTRODE, by R. R. Witherspoon, Herman Urbach, Ernest Yeager and Frank Hovorka. 142p., figs., Oct. 1, 1954. (Tech. Rept. 4) (Contract Nonr 58100) (PB 137937)

The kinetics of the oxygen electrode are studied on carbon surfaces by means of cathodic polarization measurements. Characteristics are obtained as a function of the type of carbon surface, the nature of the electrolyte, ionic strength, pH, peroxide concentration, temperature, oxygen pressure, current density, time, and catalysts included with the carbon. Bibliography, p. 134-137.

2592
Western Reserve University. Ultrasonic and Electrochemistry Research Laboratory, Cleveland, Ohio. THE OXYGEN ELECTRODE ON CARBON SURFACES, by M. O. Davies, Milton Clark, et al. 106p., illus., Nov. 15, 1959. (AD-237 103)

Anodic and cathodic polarization measurements and differential capacitance measurements have been made by interrupter techniques for the oxygen-hydrogen peroxide couple in alkaline solutions with carbon electrodes of the semilyophobic type. The results of these measurements have been compared with the surface area, pore distribution, and resistance for a large number of active carbons with different physical properties from various manufacturers.

2593
Western Reserve University. Ultrasonics and Electrochemistry Research Laboratories, Cleveland, Ohio. THE STUDY OF THE KINETICS OF THE HYDROGEN, OXYGEN AND RELATED ELECTRODES, by Ernest Yeager, Harry Dietrick and Frank Hovorka. 44p., Dec. 15, 1951. (Tech. Rept. 1) (Contract Nonr 58100) (PB 147809)

Related electrodes such as alkali metal amalgams, aluminum, and magnesium are also considered for use in heavy duty primary cells.

4. Primary

2594
Brouillet, P. and Jolas, F. PROBLEMES CONCERNANT LES ANODES DANS LES CELLULES PRIMAIRES. (PROBLEMS CONCERNING ANODES IN PRIMARY CELLS). Electrochim. Acta 1:246-260, Jly. 1959.

In French. Electrochemical criteria to which system metal-solution should conform if it is to be used as anode in primary cell; possible use of various metals, either pure or as alloys; from thermodynamic aspect; example of zinc and magnesium; measurements of variation of potential and amount of anodic decomposition.

a. Hydrogen-Oxygen

2595
Bacon, F. T. FUEL CELL RESEARCH. Times Sci. Rev. no. 20, p. 6-9, Summer, 1956.

Review, with notes on present state of development. Classical and recent researches on gas cells. High-pressure hydrogen-oxygen cell: factors leading to selection of nickel electrodes; main cell parts are Ni-plated steel. Proposed applications. (Fuel Cell Bib., Mond Nickel, Co., 1960)

2596
Bacon, F. T. THE HYDROGEN-OXYGEN FUEL CELL. Natl. Res. Devlpmt. Corp. Bull. no. 14, p.29-32, 1959.

Description of project financed by N.R.D.C., placed development contract with Marshall, Cambridge. Electrodes are of porous sintered Ni and main cell components of Ni-plated steel or Ni. Electrolyte is strong potash solution. Li atoms are incorporated into lattice of Ni oxide, converting ordinary green oxide (insulator) into black NiLi oxide (good semiconductor). (Fuel Cell Bib., Mond Nickel Co., 1960)

2597
Bacon, F. T. NEW POWER SOURCE. Commonwealth Engr. 47:36-38, Oct. 1959.

Prototype hydrogen-oxygen cell demonstrated at Cambridge University has many possible applications as direct source of electric power for traction and propulsion; development of high-temperature fuel cell. (Eng. Index p. 507, 1960)

2598
BACON FUEL CELL. Chem. & Indus. p. 1132-1133, Sept. 5, 1959.

A progress report on the Hydrox fuel cell, an electrochemical invented by F. T. Bacon and under development in England.

2599
Beach Aircraft Corp., Wichita, Kans. HYDROGEN-OXYGEN FUEL ELECTROLYTE BATTERY CONTAINER STUDY, by J. R. DeHann and M. Piccone. 97p., Oct. 1958. (WADC TR 58-542) (Contract AF33(616)5833) (AD-203 521) (PB 147 268)

Various methods of storing hydrogen and oxygen to support an electrochemical reaction fuel cell have been studied. The storage methods studied include liquid hydrogen and oxygen at 20 psia, 90 psia, and 800 psia; gaseous hydrogen at 6000 psia and 93°K, and gaseous oxygen at 6000 psia. Various insulation methods were studied and their applicability to specific missions were discussed.

2600
British Electrical Allied Industries Research Association, London. RESEARCH INTO THE PROPERTIES OF THE HYDROGEN-OXYGEN CELL. Oct. 1953. (Tech. Rept. Z/T 94)

Historical review of early work leading to plans for research by Bacon. Principles of operation of cell. Results of previous experiments (1939, 1940) and types of cell used. Description of new apparatus for present experiments incorporates porous Ni electrodes (made by Mond). Main cell parts of Ni-plated steel; pipe-works of Ni. Results and notes on future work. Proposed applications of the cell and probable advantages. (Fuel Cell Bib. Mond Nickel Co. 1960)

2601
ENTER FUEL CELL, NEW POWER SOURCE. Power Eng. 61(11):63, 1957.

Direct conversion of chemical energy of gases into electricity accomplished with new fuel cell, developed by National Carbon Co. Hydrogen and oxygen gases enter cell through specially treated hollow, porous carbon electrodes, and diffuse to surface where they come in contact with electrolyte. The fuel cell operates at temperature range from 120-140°F at 65 to 80% efficiency. In addition to military communication systems, the cell may be used for mobile power units, standby plants.

2602
EXPERIMENTAL FUEL CELL. Electron. Indus. 19:5, Nov. 1960.

"An experimental fuel cell that converts unpurified air and ordinary hydrogen gas directly into electric power has been developed by Ionics, Inc. Keys to the process are: (1) combination of fuel electrode and ionics, and membrane similar to those used in water desalting plants; (2) platinum-coated electrode; (3) bromine-bromide acid solution in cell to facilitate utilization to produce power." Entire item quoted.

2603
FUEL CELL: COMPETITOR OR CONSUMER? Oil & Gas J. 57:72-73, Feb. 9, 1959.

Description and principles of fuel cell developed by National Carbon Co., which electrochemically burns, inter alia, H and O as fuel to produce electric energy. Types are direct fuel cells using solid fuel, semi-direct using gaseous fuel, and indirect using oxidation-reduction system (Redox). List of firms undertaking development is given. Commercial conversion efficiency up to 90% against 35-40% efficiency in petrol engine. (Fuel Cell Bib., Mond Nickel Co., 1960)

2604
FUEL CELL MAY HAVE A SATELLITE APPLICATION. Aviat. Wk. 70:173, June 22, 1959.

A new fuel cell is illustrated which features a plastic ion exchange membrane in place of usual aqueous electrolyte. The unit has shown 60 o/o thermal efficiency in the production of electricity from reaction of hydrogen and oxygen.

2605
FUEL CELL: POTENTIAL COMMERCIAL USE. Financial Times p. 9, Oct. 3, 1957.

Cell, generating electricity from chemical reaction between oxygen and hydrogen developed recently for use in U.S. Army portable field radar, is stated to have possible commercial use. Prototype consists of plastic jar enclosing 9 hollow C electrodes surrounded by K hydroxide. Cell is capable of lasting indefinitely as long as supply of oxygen and hydrogen is continued. No cell elements are consumed. For low electric power levels, air can be substituted for oxygen.

2606
FUEL CELL PROGRESS. Engr. 208:154, 1959.

A progress report on the "Hydrox" cell. The stage of progress marked by the demonstration of a battery of forty hydrogen-oxygen fuel cells supplying electric power for industrial equipment was the production of fully automatic control apparatus capable of working unattended.

2607
G. E. DEVELOPS HYDROGEN-OXYGEN FUEL CELL. Elec. World 151:64, 68, June 15, 1959.

Brief description of cell which operates efficiently at room temperature and normal atmospheric pressure. Thermal efficiencies over 60% have been obtained.

2608
General Electric Co. Missile and Space Vehicle Dept., Philadelphia, Pa. INVESTIGATION AND TEST OF ION EXCHANGE MEMBRANE FUEL CELLS. 10p., Nov. 30, 1960. (Tech. Prog. Rept. 1) (Contract AF33(616)7579)

During this report period, the major effort has been on testing a 50-watt size fuel cell battery. So far, it has been possible to cycle the battery repetitively for only two charge-discharge cycles. Failure has been attributed to intercell leakage of hydrogen and oxygen, residual atmospheric oxygen in the hydrogen compartment, and leakage of gases through the membrane. Polarization curves have been made on single cells of the 50-watt design; these indicate that the unit should have a peak power output of approximately 160 watts.

2609
Grubb, W. T. and Niedrach, L. W. BATTERIES WITH SOLID ION-EXCHANGE MEMBRANE ELECTROLYTES. Part II - LOW TEMPERATURE HYDROGEN-OXYGEN FUEL CELLS. Electrochem. Soc. J. 107: 131-135, 1960.

Hydrogen-oxygen fuel cells employing a commercial ion-exchange membrane as the electrolyte are described. Some performance data on this type of cell operating at room temperature with a cation membrane in the hydrogen form and with hydrogen and oxygen at 1 atm are presented. The open circuit emf is about 0.3 v below the value of 1.23 expected for a reversible cell. This deficiency is found to be caused by the oxygen electrode which does not achieve the reversible half-cell potential. Equilibration of the membrane electrolyte with sulfuric acid prior to cell assembly results in improved polarization characteristics. Favorable features of these cells include their simple construction and their small unit thickness. In addition, the presence of as much as 67% CO_2 in the hydrogen feed gas is found to have little effect upon performance. Since the electrolyte is a cross-linked, water-saturated polymer, the electrolyte is locked into the structure and cannot be leached from the cell when it is operated within the stability limits of the polymer. No dilution occurs from the water formed at the oxygen electrode during cell operation because it is rejected from the saturated electrolyte.

2610
Hinch, R. R. THE FUEL CELL. Georgia Tech. Engr. 21:36-37, 44, Dec. 1959.

General information relative to the need for new methods of producing power is given as a background, then the concept of the fuel cell is traced. The article concludes with a detailed description of the fuel cell developed by the National Carbon Co.

2611
ION-MEMBRANE FUEL CELL. Electromech. Design (no. 6) 4:24-26, 1960.

Solid electrolyte makes direct chemical-to-electrical energy conversion a practical power source.

2612
Ionics, Inc., Cambridge, Mass. STUDY OF ION EXCHANGE MEMBRANE FUEL CELL COMPONENTS, Monthly Report, by R. M. Lurie and R. Schuman. 7p., illus., Dec. 30, 1960. (Contract DA44-009-eng 4554) (AD-252 024)

A study is being made of the H-O ion exchange membrane fuel cell to determine the factors which limit the performance of the cell, such as impurities in the H and O stream. The electrodes and membranes will be studied. Two methods for testing electrodes and 3 methods for measuring the properties of membranes are being utilized. A Br-H fuel cell (Fuelox cell) was constructed with an H electrode, a standard 4-oz cation membrane, and a bromine-bromide solution electrode. Electrode-membrane half cells were studied with H and O as well as N as a control gas. Results indicated that membrane or membrane-catalyst interface is the source of major resistance.

2613
Ionics, Inc., Cambridge, Mass. STUDY OF ION EXCHANGE MEMBRANE FUEL CELL COMPONENTS. Monthly Report, by R. M. Lurie and R. Schuman. 4p., tables, Feb. 7, 1961. (Contract DA44-009-eng-4554) (AD-252 025)

Emphasis was placed on testing membranes and catalysts in order to minimize the internal resistance of the fuel cell and optimize its performance. The membranes tested were composed of styrene sulfonic acid, phenol sulfonic acid-formaldehyde, carboxylic acid-polyethylene, and styrene quaternary ammonium. The catalyst forms included: (1) graphite support, placed next to the membrane; (2) graphite support,

embedded in membrane; and (3) catalyst plated on membrane. The membranes were evaluated in dry cells and in half cells. The water content of the membrane had no effect on the resistance as measured in a half cell, and a small effect as measured in the dry cell. Improved performance was obtained by bubbling the gas going to the test electrode through hot H_2O and thereby adding moisture to the electrode chamber gradually, and by plating Pt on the membrane.

2614
JAPANESE FUEL CELL GOES INTO COMMERCIAL PRODUCTION. Prod. Eng. 32:9, Jly. 17, 1961.

"Openly challenging American manufacturers, Matsushita Electric Industrial Company of Osaka is planning to produce a low-temperature, low pressure hydrogen-oxygen fuel cell of the carbon electrode type. The prototype model, shown here running a toy train, consists of 10 cells (1 volt, 3 amp) and weighs 11 lb. Thermal efficiency, says Matsushita, is 70 %. Hydrogen gas is the fuel, air is the oxidant, and caustic soda is the electrolyte. The carbon electrodes are "hollow, waterproof cylinders." Entire item quoted.

2615
NEW ELECTRODE BOOSTS FUEL-CELL POWER FOURFOLD. Chem. Eng. 67:83, Sept. 19, 1960. Also in Oil Gas J. 58:76, Sept. 19, 1960.

The Shell Company has developed a low-temperature hydrogen-oxygen cell with a "radically different" electrode which is capable of developing 3 to 5 k W/ft^3, about four times the present output of low-temperature cells. At room temperature, the cell achieves a current density of 70 amp/ft^2; it uses acid or alkaline electrolytes, and operates at 3 psig on air or oxygen. Power-to-weight ratios of up to 50 W/lb are expected with this new electrode. (Fuel Abs. & Current Titles 2:338, Jan. 1961)

2616
NEW FUEL CELL. Financial Times, p. 13, June 12, 1959.

Note on lightweight, compact "gaseous fuel cell" which can generate low-voltage d. c. more efficiently than conventional methods. Prototype is hollow plastic disc containing two chambers: hydrogen is introduced into one chamber and oxygen into the other.

2617
NEW FUEL CELL. Chem. Process Eng. 41:434, Oct. 1960.

Brief mention is made of the Thornton fuel cell. When run on hydrogen and oxygen at a pressure of 3 psi, current densities of 70 amp/sq/ft/ can be readily obtained with both types of electrolyte (acid or alkaline) at room temperature.

2618
NEW GALVANIC CELL USES OXYGEN, HYDROGEN. Chem. Eng. 62:136, Sept. 1955.

Short description of the Bacon fuel cell. In cell are porous Ni electrodes contained between the halves of a Ni-plated cylinder with 27% potassium hydroxide solution between the electrodes. Thin layer of Ni oxide encases the positive electrode.

2619
NEW PROGRESS IN FUEL CELLS. Mach. Design 31:10, diags., June 11, 1959.

"Fuel cells with ion exchange membrane electrolytes are reported practical by General Electric. These new cells solve problems of ion leakage, water collection at fuel electrode, and electrolyte dilution. In GE working models, hydrogen is fed into one chamber and oxygen into another. Hydrogen ions pass through the membrane to the oxidant electrode where water is formed. Electrons from the fuel electrode arrive via the external electric circuit. More than 60 per cent of

heat released by combustion is converted to electricity. Power densities as high as 2 kw per cu ft are predicted." Entire item quoted.

2620
Oster, E. A. CATION-EXCHANGE-MEMBRANE FUEL-CELLS. In Power Sources Conference. Proceedings, 14th, p. 59-62, Red Bank, N. J., PSC Publications Committee, 1960.

As a result of improvements in the ion-exchange fuel-cell which indicated that this device was a practical source of power for special applications, development of the cell for air-breathing portable ground-power units is detailed.

2621
Paton, A. P. THE BACON HYDROGEN-OXYGEN FUEL CELL. Coop. Elec. Res. no. 4, p. 30-31, Jan. 1958.

Cell comprises two porous Ni electrodes in KOH solution. (Fuel Cells Bib., Mond Nickel Co., 1960)

2622
Perry, John, Jr. ANION EXCHANGE MEMBRANE FUEL CELLS. In Power Sources Conference. Proceedings, 14th, p. 50-52, Red Bank, N. J., PSC Publications Committee, 1960.

Advantages are mentioned of ion exchange membrane fuel cell batteries as power supplies for possible military application. These batteries, operating at ambient temperatures and pressures, with hydrogen as fuel and oxygen or air as oxidant, could be used as power sources in a power range from 50 watts up to 1 kilowatt. These fuel cell batteries could also be incorporated in regenerative systems for space applications where they could serve as energy storage devices.

Studies at the U.S. Army Signal Research and Development Laboratory to determine the problems involved are reported.

2623
PRACTICAL FUEL CELL GIVES ELECTRIC POWER. Eng. 188: 106, Aug. 28, 1959.

How the Bacon Hydrox fuel cell works and its applications.

2624
Pshenichnikov, A. G. TRANSFORMATION OF THE CHEMICAL ENERGY OF FUEL INTO ELECTRICAL ENERGY IN FUEL CELLS. Teploenergetika 10:47-51, 1956.

In Russian. Trans. by Aerospace Technical Intelligence Center, Wright-Patterson AFB, no. MCL-401. (AD-255 375) Available from OTS.

The advantages and the possible application areas of the hydrogen-oxygen fuel cells at the present time include: (1) a fuller utilization of the energy of fuel than in a heat engine; (2) the ability to carry heavy loads with a reduced efficiency and to yield low-voltage dc promises an application of the hydrogen-oxygen cell in the transportation field; (3) actual absence of moving parts, complete noiselessness, and freedom from vibration; (4) the cell coupled with an electrolyzer can be used as a storage battery, and there is no need to increase the dimensions of the cell with increased amount of energy stored, since hydrogen and oxygen obtained through the electrolysis are stored in tanks; (5) with a power of 1 - 2 kw and more, a cell with tanks will be lighter and more compact than ordinary storage batteries with the same amount of energy stored; (6) the use of the hydrogen-oxygen cell as a storage battery is advisable for storing wind energy; and (7) the efficiency of an electrolyzer-fuel cell couple is 40%.

2625
RESEARCH ON HYDRO-OXYGEN CELLS. Chem. Age. 73:1163, 1955.

Minister of Fuel and Power reported in British House of Commons on

November 14 on progress in research on production of electric power by H-O cells. Government has contributed £9,000 since 1951 for this purpose. Bacon cell has reached encouraging stage of technical development. Commercial development being studied.

2626
Riggs, J. R. RESURGENCE OF THE FUEL CELL. Elec. Mfg. 62:12, Dec., 1958.

Research note, describes work done, particularly by research engineers at Allis-Chalmers, with a 24-volt, 30-watt unit powered by hydrogen and oxygen.

2627
U.S. Army. Engineer Research and Development Laboratories, Ft. Belvoir, Va. OBSERVATIONS ON THE CURRENT DEVELOPMENTS OF THE BACON HYDROGEN/OXYGEN FUEL CELL, by F. M. Baumgardner. 59p., illus., Jly. 25, 1958. (AD-220 062)

Contents. An outline of the properties of the Bacon hydrogen/oxygen fuel cell with additional notes on the Sondes Place Research Institute primary cell development;

Development testing of the Bacon hydrogen/oxygen fuel cell;

Factors to be considered in the engineering of a practical hydrogen/oxygen fuel cell pack;

Designs for a gas control system for hydrogen/oxygen fuel cell pack;

Designs for the storage and handling of liquid or gaseous hydrogen and oxygen as required for operation of the hydrox cell system;

The Bacon hydrogen/oxygen fuel cell as a reversible cell (electrolyzer);

Applications of the Bacon hydrogen/oxygen fuel cell.

2628
U.S. Army. Signal Research and Development Laboratory, Ft. Monmouth, N. J. INVESTIGATION OF THE HYDROGEN-OXYGEN FUEL CELL, by H. Hunger. 55p., Dec. 15, 1958. (Tech. Rept. 2001) (AD-219 732)

Results are presented to advance the general knowledge of fuel cells and to provide a basis for the construction of a practical hydrogen-oxygen fuel cell. These cells, if available, would have a broad area of application and could be employed as medium power sources in performance range between 10^2 and 10^5 watt. New information, offered as a result of this investigation, includes the importance of a preliminary CO_2 gas activation on the current-carrying ability of the hydrogen electrodes, the theoretical conclusions concerning gas transportation to the reaction zone, and the influence of the wet-proofing treatment on this transportation.

2629
ZERO GRAVITY FUEL CELL. Missile Design & Devlpmt. 6:32, Nov. 1960.

"Zero gravity fuel cell operation studies have been conducted by Beechcraft Research and Development, Boulder, Colo., with an eye to possible satellite auxiliary power use. Various methods of storing hydrogen and oxygen, and insulation methods, were among the research items." Entire item quoted.

b. Carbonaceous

2630
DeZubay, E. A. HYDROCARBON-AIR FUEL CELL. Soc. Automotive Engrs. J. 68:35-37, Jly. 1960.

Only economic fuel cell for motor vehicles is a hydrocarbon-air cell. But current densities (amp/sq ft) must be increased and initial costs reduced to make it practical. Best chance for early success of this cell lies in the high-temperature, molten carbon cell. The carbonaceous liquid fuel-atmospheric air cell can produce power at a very attractive operating cost - 1/2 to

4 cents/kwhr (depending on component efficiencies and direct cost of fuel). At present, the initial cost of hydrocarbon fuel-air cells is high due to the material requirements and fabrication techniques. In contrast, low-initial-cost cells have high operating costs due to their stored oxygen requirements.

2631
FUEL CELLS OPERATING AT 100°F, USING MOLTEN-SALT ELECTROLYTES. Prod. Eng. 30:8, June 15, 1959.

Brief reference is made to a report by H. A. Liebhafsky and D. I. Douglas at an ASME meeting. In the high temperature fuel cells referred to, the fuel (hydrogen or a hydrocarbon) is fed into the cell through one electrode, oxygen or air through the other. The fuel is oxidized at the anode and oxygen consumed at the cathode, causing a current to flow external to the cell.

2632
FUEL CELLS UTILIZING LIQUID FUELS. Engrs. Dig. 20:12, Dec. 1959.

A recent patent envisages the production of electrical energy in a fuel cell from a liquid fuel. Briefly, the characteristic features of the new cell are that the combustible liquid is intimately mixed with the liquid electrolyte and that the oxygen electrode of the cell is inert to this mixture.

2633
Gamburg, D. Yu. THE FUEL CELL. Nauka i Zhizn 25:17-22, 1958.

In Russian. Trans. 60-13815 available from LC or SLA. Extracts also in Great Britain, DSI. 538.

Concerns use of hydrocarbon fuel in cells with solid electrolytes.

2634
HYDROGEN, ETHANE POWER FUEL CELLS. Chem. Eng. 65:49, Nov. 3, 1958.

Brief mention of a hydrogen-oxygen fuel cell developed by Allis-Chalmers.

2635
Pittsburgh Consolidation Coal Co., Library, Pa. CONVERSION OF CARBONACEOUS FUELS TO ELECTRICAL ENERGY, by Everett Gorin and H. L. Recht. 12 issues, 1954, 1957. (Quart. Repts. 1 through 11, and Final) (Contract DA36-039-sc-63090) (AD-69 478, AD-69 479, AD-60 480, AD-69 501, AD-77 114, AD-80 591, AD-89 805, AD-107 013, AD-113 204, AD-123 123, AD-128 121, AD-143 452)

Development progress is reported for an integrated fuel cell gasification system for the generation of electrical power from carbonaceous fuels. A high-temperature gaseous fuel cell was being constructed which would use a solid electrolyte of the type being developed by Davtyan (Acad. Sci. USSR. Bull. no. 2:215-218, 1946).

2636
Pittsburgh Consolidation Coal Co., Library, Pa. CONVERSION OF CARBONACEOUS FUELS TO ELECTRICAL ENERGY, by Everett Gorin and H. L. Recht. 4 issues, 1957, 1958. (Quart. Repts. 1, 2, 3, and Final) (Contract DA36-039-sc-74941) (AD-202 966, AD-202 967, AD-200 879, AD-204 666)

Concerns efforts directed towards the development of a cell which may be used in an integrated fuel cell gasification system. An analysis was made of the factors which limit the ultimate performance that can be achieved from a high temperature fuel cell.

2637
Resin Research Laboratories, Newark, N. J. ORGANIC FUEL CELL SYSTEM, by G. A. Baum. 74p., illus., Nov. 1960. (WADC TR 59-780) (Contract AF33(616)6399) (AD-254 076)

Attempts were made to determine the feasibility of developing an organic fuel cell system for use as an electrical power source in future USAF space applications. Initial results showed that: (1) liquid cathode fuels were preferred for systems utilizing magnesium as the anode fuel; and (2) mononitro compounds were preferred to di- and tri-nitro compounds. Subsequent results indicated that: (1) due to problems of both a theoretical and practical nature, neither magnesium nor aluminum could be used as anode materials despite their theoretically attractive electrochemical potentials and coulombic capacities; and (2) formidable problems existed in regard to efficient utilization of nitro compounds being used as cathode fuels. A theoretical investigation indicated the inapplicability of a regeneration system for the foregoing cathode fuels. (TAB p.24, June 1, 1961)

2638
REVOLUTIONARY BATTERY DEVELOPMENT IN HOLLAND. Chem. Age 83:245, 1960.

Report of claim by Prof. J. Ketelaar, Amsterdam Municipal University, that he has developed electromotor fed by battery, which might replace automobile engine within 25 years based on pioneer work of Russian scientists, particularly Davtyan. Fuel element is fed by coal gas and air. Electricity, not heat, is generated on burning CO. (Fuel Cells Bib., Mond Nickel Co., 1960)

2639
Wynn, J. E. LIQUID FUEL CELLS. In Power Sources Conference. Proceedings. 14th, p. 52-55, Red Bank, N.J., PSC Publications Committee, 1960.

Experiments undertaken at the U.S. Army Signal Research and Development Laboratory suggest that liquid organic compounds can be oxidized electrochemically in fuel cells at room temperature at promising oxidation rates. However, many problems have to be solved in order to obtain practical batteries with long operational lives. Since various liquid organic compounds are potential fuels for this type of system, a fuel cell battery developed on this principle could offer many advantages in a variety of military and commercial applications.

5. Regenerative

2640
Boeing Airplane Co., Seattle, Wash. SR-183 LUNAR OBSERVATORY. A SURVEY OF REGENERATIVE SYSTEMS FOR ELECTROCHEMICAL CELLS, by R. A. Johnson and E. Kawaski. 47p. Sept. 30, 1959. (Rept. D2-3645) (Contract AF18(600) 1824) (AD-232 319)

Survey of closed regenerative electrochemical cell systems is discussed for use as secondary power sources in sustained flight vehicles. The possibility of adapting conventional fuel cells, to a regenerative system is considered. Systems utilizing direct inorganic combinations reactions are discussed, as well as systems utilizing photosensitized organic reactions. Thermogalvanic cells are also considered. Results indicate that hydrogen halides offered the most promising inorganic reactions for development as regenerative fuel cell systems. The improvement of the photocatalytic decomposition of water would make the use of regenerative hydrogen-oxygen fuel systems possible.

2641
BOOST FUEL CELL STORAGE. Sun at Work 5:5, Jly/Sept. 1960.

The development of an experimental model of a lightweight regenerative fuel cell with storage capabilities several times greater than conventional battery devices is discussed.

2642
Del Duca, M. G., Fuscoe, J. M., and Johnston, T. A. REGENERATIVE FUEL CELLS AS AUXILIARY SUPPLIES FOR SPACE VEHICLES. ARS Paper 1039-59,

New York, American Rocket Society, 1959.

Paper presented at the ARS 14th Annual Meeting, Washington, D. C., Nov. 16-20, 1959.

Special requirements of auxiliary power units for space applications such as start-up, radiators, shielding the effects of space environment, etc., are considered. A detailed analysis of a nuclear regenerative fuel cell system using lithium and hydrogen as fuels with a power output of 550 watts at 28 volts is presented along with a discussion of the optimization procedure utilized in the derivation of the conceptual design. Performance parameters of selected systems are itemized.

2643
Electro-Optical Systems, Inc., Pasadena, Calif. INVESTIGATION OF NEW SOLAR REGENERATIVE FUEL CELL SYSTEMS, by F. Ludwig. 7p., Jan. 10, 1960. (Semi-annual Tech. Summary Rept. 1) (Rept. 420-2Q-1) (Contract DA36-039-sc-85270) (AD-233 236)

Experimental data on fuel cells is used as a basis for theoretical studies and for obtaining actual performance figures such as energy/weight for electrically regenerated or reversible fuel cells and power/weight for the strictly regenerative cells. Results indicate that the weight of a solar cell reversible fuel cell system where the fuel cell is used as a storage battery can be equal to or less than the weight of the conventional solar regenerative fuel cell. The weight of a specially designed reversible fuel cell may be much less under conditions met in satellites than the weight of a conventional storage battery such as the nickel-cadmium battery (for discharge periods such as 1/2 hour). Both conventional solar regenerative fuel cell and reversible fuel cell concepts are investigated.

2644
Electro-Optical Systems, Inc., Pasadena, Calif. INVESTIGATION OF NEW SOLAR REGENERATIVE FUEL CELL SYSTEMS, by F. A. Ludwig. 169p., Jly. 10, 1960. (Semiannual Tech. Summary Rept. 2) (Rept. 420-2Q-2) (Contract DA36-039-sc-85270) (AD-255 462)

New concepts for solar regenerative fuel cells were explored analytically and experimentally. An analytical program to determine the importance of storage capabilities of a thermally regenerative fuel cell pointed out that this feature may be ignored when evaluating the general efficiency.

Theoretical efficiency was determined by setting up 12 models.

A brief analysis of the efficiency of photochemically regenerative fuel cells was made.

2645
Electro-Optical Systems, Inc., Pasadena, Calif. INVESTIGATION OF NEW SOLAR REGENERATIVE FUEL CELL SYSTEMS. Final Report. 1/2 in. thick, Nov. 30, 1960. (Rept. 420) (Contract DA36-039-sc-85270) (AD-255 463)

An analysis to compare efficiencies of regenerative fuel cells; survey of compounds for, and development of concepts for, thermally regenerative fuel cells.

2646
Finkelstein, Theodor. REGENERATIVE THERMAL MACHINES. Battelle Tech. Rev. 10:3-9, illus., May 1961.

Invented almost 150 years ago as the Stirling engine, regenerative thermal machines promise efficient power generation and performance of other useful functions for today's technology.

2647
Florida University, Gainesville, Fla. HYDROCARBON REGENERATION OF THE ANOLYTE IN A REDOX FUEL CELL, by J. C. Mallon and R. D. Walker. 18p., Mar. 18, 1960. (Spec. Rept. 1) (Contract DAI 49-186-502-ORD(P)-860) (AD-244 081)

The importance of regeneration in redox fuel cells is very briefly discussed, and it is shown that there is little knowledge concerning the nature or extent of the reactions involved. Thermodynamic methods have been brought to bear upon the oxidation of lower normal paraffin hydrocarbons to alcohols in an effort to estimate the relative difficulty of a possible first step in the complete oxidation of the hydrocarbon to carbon dioxide and water.

2648
Florida University, Gainesville, Fla. PRELIMINARY CALCULATIONS OF THE REGENERATION AND RECOVERY REQUIREMENTS FOR A BROMIDE-BROMINE ELECTRODE FOR A REDOX FUEL CELL, by W. E. Reneke. 22p., June 15, 1960. (Spec. Rept. 2) (Contract DAI-49-185-502-ORD(P)-860) (AD-243 517)

All calculations in this design are based on isothermal operation at either 20° or 25°C. No data were available at other temperatures. The regeneration tower requirements are based on Posner's paper (Am. Chem. Soc. J. 7:2634, 1955) dealing with the air regeneration of bromine with a nitrogen oxide catalyst. This paper did not give sufficient data for an exact design procedure. Based on his statement that the same results were obtained with the flow and batch apparatus, the column was sized from the residence time required to complete the same degree of regeneration in a batch operation. It was assumed that the tower had 68% free volume and that 50% of this volume was vapor space. The design calculations were all based on the requirements of a fuel cell with a rated power output of 10 kilowatts.

2649
Friauf, J. B. THERMODYNAMICS OF THERMALLY REGENERATED FUEL CELLS. J. Appl. Phys. 32: 616-620, figs., Apr. 1961.

It is shown that $d(\theta\Delta H)/dT = 0$ is a necessary condition for the attainment of Carnot cycle efficiency, $(T_1 - T_2)/T_1$, by a thermally regenerative fuel cell system in which ideal gases are reacted in a fuel cell to convert chemical to electrical energy, and are then regenerated for recycling by thermal dissociation of the product of the reaction, also assumed to be an ideal gas.

2650
FUEL CELLS FOR SATELLITES DEVELOPED BY AIR FORCE. Sci. New Ltr. 79:213, Apr. 8, 1961.

Brief article relative to the imminent testing of newly developed regenerative fuel cells for auxiliary power in orbiting satellites.

2651
Lockheed Aircraft Corp., Sunnyvale, Calif. SOLAR REGENERATIVE CHEMICAL SYSTEM, by H. P. Silverman. 3 issues, Jan. Jly. Dec. 1960. (Semiannual Repts. 1, 2, 3) (Repts. LMSD 288152, 703039, 895034) (Contract DA36-039-sc-85245) (AD-233 858, AD-242 591, AD-254 841)

The use of regenerative fuel cells for the conversion of solar energy into electrical energy is discussed.

2652
McCully, C. R. THE CHEMICAL CONVERSION OF SOLAR ENERGY TO ELECTRICAL ENERGY. 17p., illus., New York, United Nations, May 16, 1961. (E/CONF. 35/GEN/6)

Preprint of paper prepared for United Nations Conference on New Sources of Energy.

Principles of the chemical conversion method are cited; the "unique" approach to the thermally regenerative galvanic cell under investigation at the Armour Research Foundation is mentioned; applications are reviewed and the conclusion reached that "in spite of their relative simplicity, conversion efficiency, and other favorable factors, thermally regenerative galvanic

cells operated from solar energy do not appear to offer a promising power source of general application unless mass production is undertaken."

2653
McKee, W. E. et al. SOLAR REGENERATIVE FUEL CELLS. In Power Sources Conference, Proceedings, 14th, p. 68-72, PSC Publications Committee, 1960, Red Bank, N. J.

This paper presents a brief discussion of some of the problems and theoretical aspects of a photochemical type of solar regenerative system. It also presents a status report on the regenerative nitrosyl chloride fuel cell system which Sundstrand is developing under contract to Wright Air Development Division, Aeronautical Accessories Laboratory, Power Branch. In this system, chlorine (Cl_2) and nitric oxide (NO) are combined in a fuel cell to produce electricity, the nitrosyl chloride (NOCl) formed in the process is subsequently photodissociated into chlorine and nitric oxide. These fuels can be stored for future use or fed back into the fuel cell.

2654
Pennsylvania State University, University Park, Pa. REDOX FUEL CELL, by L. G. Austin. 4 issues, 1960, 1961. (Quart. Prog. Repts. 1, 2, 4, 5) (Contract DA49-186-502-ORD-917) (AD-243 588, AD-243 589, AD-253 598, AD-258 772)

A theoretical discussion is presented of the fuel regenerator in a redox fuel cell. Four electrochemical steps were considered, including: (1) the regeneration of the anodic-ionic couple by a chemical fuel; (2) the electrochemical anode reaction; (3) the electrochemical cathode reaction; and (4) the regeneration of the cathodic couple using oxygen. The analysis led to the conclusion that polarization due to free energy losses in the fuel regenerator will not be serious until the limiting current, i.e. the current reached when C becomes zero, is attained.

2655
PERPETUAL FUEL CELL NEXT? Missiles & Rockets 8:29, May 29, 1961.

"An experimental regenerative fuel cell which can be designed to deliver thousands of kilowatts and operate indefinitely is under development at Hoffman Electronics. A working model of the sodium amalgam-chlorine primary fuel cell, not much larger than a man's wrist watch, produces 1 watt of power, compared with 2/3 watt from a flashlight cell. It also can use bromine to generate electricity by chemical reaction, according to Hoffman." Entire item quoted.

2656
Podolny, W. H. REGENERATIVE H_2O_2 FUEL CELL SYSTEM. In Power Sources Conference. Proceedings, 14th, p. 64-67, Red Bank, N. J., PSC Publications Committee, 1960.

An investigation is related of an energy storage system utilizing an oxygen and hydrogen fuel cell and an electrolysis cell. Purpose of the program has been to conduct research on the major components to establish the feasibility of such a system.

2657
Snoke, D. R. and Fuscoe, J. M. LITHIUM HYDROGEN REGENERATIVE FUEL CELL SYSTEM. SAE International Congress & Exposition of Automotive Engineers, Detroit, Mich., Jan. 9-13, 1961. Preprint 308D, 8p. Also in SAE. J. 69:68-69, June 1961.

Discussion of the principles underlying the lithium-hydrogen fuel cell. Auxiliary components necessary for a complete fuel cell system are considered. Such a system is described, and its operational characteristics are presented. (Intern. Aerospace Abs. 61-2391)

2658
TARGET: MORE VERSATILE FUEL CELLS. Chem. Wk. 88:43-44, 46, May 27, 1961.

Various types of fuel cells are described and a table is included with listings of companies working on regenerative fuel cells, the fuel being used, the oxidizer, the product, the energy source, and the status of development.

B. Primary Batteries

2659
Aerojet-General Corp., Azusa, Calif. DEVELOPMENT OF CHLORINE-DEPOLARIZED BATTERIES, by E. P. Davis, L. J. Gordon, et al. 4 issues, 1953, 1954. (Repts. 3825-1, 2, 3, Final) (Contract DA36-039-sc-42706) (AD-20 445, AD-20 446, AD-24 717, AD-32 709)

An investigation was conducted to develop a highrate primary battery suitable for use as a missile electrical supply.

2660
Aerojet-General Corp., Azusa, Calif. AN INVESTIGATION LEADING TO THE DEVELOPMENT OF CHLORINE-DEPOLARIZED BATTERIES FOR GUIDED MISSILES, DEVELOPMENT OF CHLORINE-DEPOLARIZED BATTERIES, by L. J. Gordon and J. D. Miller. 8 issues, 1954, 1955, 1956. (Quart. Repts. 1 through 7, Final) (Contract DA36-039-sc-56742) (AD-40 480, AD-53 165, AD-69 485, AD-66 721, AD-78 299, AD-86 070, AD-96 275)

The device is a compact, automatically activated, reserve missile battery. The specific energy of the system is above 25 w-hr/lb. A shelf life of at least 10 mo was demonstrated for some batteries. The battery system utilizes the Zn-Cl electrochemical couple. The battery consists of a Zn, electrolyte, and C cathode structure assembled in bipolar series units; the Cl depolarizer is stored separately in an electrically opened container within the battery case. The system offers the advantages of a high energy per unit weight and volume.

2661
Aerojet-General Corp., Azusa, Calif. AN INVESTIGATION LEADING TO THE DEVELOPMENT OF CHLORINE-DEPOLARIZED BATTERIES FOR GUIDED MISSILES. Final Report, by S. B. Kilner, E. M. Langworthy, and H. E. Lawson. 1 vl., illus., Apr. 30, 1957. (Rept. 1254) (Contract DA36-039-sc-71209) (AD-138 363)

Progress in the development of a high-rate primary battery is summarized. The cells are of the bipolar type with the gas diffuser of one cell bonded to the metal anode of the next cell in series. The electrolyte salts are installed at the time of manufacture. Data indicated that a thoroughly desiccated battery, which may be stored under any field conditions for an indeterminate period, may be armed by injecting water into the case and allowing water-vapor transfer to take place for several days. After arming, the battery may be stored for at least an additional year under field conditions and be ready for immediate use during this period. Activation times of 0.4 sec at 160°F, 1.4 sec at 70°F and 42 sec at -22°F were recorded for 20-cell batteries. Life on load is not appreciably affected by starting temperatures as low as -54°F. A new method of assembly simplified construction and made the use of superior electrolytes possible. The new mixed-salt electrolytes (23.6% $CaCl_2$, 7.5% $ZnCl_2$) make possible near-infinite storage in the dry state, moisture arming, better voltage regulation, longer discharge life in a 20-cell stack, low-temperature operation, and improved shelf life after arming. When properly designed, the battery may be partially activated and discharged, then allowed to stand for up to 4 hr, and finally reactivated and completely discharged with no loss in total output.

2662
Aerojet-General Corp., Azusa, Calif. RESEARCH ON ELECTROCHEMICAL FUEL CELLS. FINAL REPORT, 15 November 1951 through 10 August 1956, by M. J. Cramer, S. B. Kilner and E. M. Langworthy. 52p., May 24, 1957. (Rept. 1233) (Contract N7onr-46207)

The general purpose of the contract work has been to determine the feasibility of employing primary batteries as the prime propulsion unit of undersea vehicles. A zinc-chlorine battery of practical design has been produced. A specific energy of 1/5 hp-hr/lb is indicated for a cruise time of 1 to 2 weeks.

2663
American Machine & Foundry Co. Engineering Laboratories, Raleigh, N. C. RESEARCH AND DEVELOPMENT OF SILVER-ZINC ELECTRONIC "A" AND "B" POWER SUPPLY FOR SPARROW I MISSILE. 9p., charts, Nov. 25, 1957. (Eng. Rept. 3412) (Contract NOas 56-826c)

A description is given of the silver-zinc battery designed to furnish power for plates and filaments in the missile control section.

2664
Bell Telephone Laboratories, Whippany, N. J. PRIME POWER SOURCES FOR THE NIKE MISSILE, by G. H. Ebel. 4p., Oct. 7, 1957. (Contract DA30-069-ORD-1082) (AD-157 036)

The search for a better prime power source for the NIKE missile led to following investigations: (1) improvement of the present nickel cadmium battery, (2) a study of a thermal type battery, (3) the development of a quick activate zinc-silver oxide battery, and (4) an investigation of an alternator run from the turbine shaft of the missile hydraulic power unit (HPU). A short summary of each investigation is presented.

2665
Catalyst Research Corp., Baltimore, Md. AUTOMATICALLY ACTIVATED ZINC SILVER OXIDE BATTERY, by J. J. Holechek, P. E. Streigle, et al. 2 issues, Sept., Dec. 1960. (Quart, Repts. 1, 2) (Contract DA36-039-sc-85361) (AD-251 986, AD-255 919)

A study has been initiated for the purpose of developing a chemically heated, automatic activation system for zinc-silver oxide batteries which will make them capable of 0.5 second activation and operation throughout the range of -65 to 165°F with close voltage regulation.

2666
Clune, R. R. RECENT DEVELOPMENTS IN THE MERCURY CELL. In Power Sources Conference. Proceedings, 14th, p. 117-120, Red Bank, N.J., PSC Publications Committee, 1960.

It is shown that the development of a modified mercury cell structure has made possible the production of low temperature dry batteries with characteristics not heretofore available in other systems; that the high stability of the mercury cell has permitted construction of Voltage Reference Batteries; and that gradual improvements in cell quality have resulted in batteries having unusually long storage life.

2667
Electric Storage Battery Co. Missile Battery Division, Raleigh, N. C. INVESTIGATION OF AgO PRIMARY BATTERIES. 2 issues, Jan. 27, May 8, 1961. (Quart. Prog. Rept. 6, 7) (Contract DA36-039-sc-78319)

Performance capability of Zn/KOH/AgO flat plate cells is reported.

2668
Euler, J. ADVANCES IN THE FIELD OF ELECTROLYTIC CURRENT GENERATORS. I-II. ETZ. 12:462-467, Sept. 19; 487-489, Oct. 3, 1960.

In German. Reviews recent advances in the field of primary batteries as electrolytic current generators. Three developments specially noted are the miniature cell, the heavy duty paper-lined cell and the alkaline primary battery. Also discussed are new systems with organic depolarizers and the introduction of the oxygen cell. (Sci. Abs. 64B:1328, 1961)

2669
General Dry Batteries, Inc., Cleveland, Ohio. DEVELOPMENT OF HIGH RATE NON-RESERVE MERCURIC OXIDE CELLS, by B. J. Garbey et al. 10 issues, 1953, 1954, 1955, 1956. (Quart. Prog. Repts. 1 through 9, Final) (Contract DA36-039-sc-52580)

An investigation was conducted to create complete specifications for a high-rate, lightweight, non-reserve A and/or B battery for 1-shot applications utilizing the Zn, GhO, KOH systems. Depolarizer development includes studies of optimum mix ratio, base metal, thickness, and variable technique. Of five suggested anode types, the sponge anode based on current-producing and efficiency tests proved overwhelmingly superior to all other types. Anode storage investigations were limited to sponge Zn.

2670
General Dry Batteries, Inc., Cleveland, Ohio. DEVELOPMENT OF HIGH RATE NON-RESERVE MERCURIC OXIDE CELLS, by Cecil Jenkins. 2 issues, Jan. 31, Apr. 30, 1956. (Repts. 1, 2) (Contract DA36-039-sc-70071) (AD-88 820, AD-97 545)

Research is being conducted to design and develop a nonreserve battery which utilizes the Zn-HgO-KOH electrochemical system for high-rate applications.

2671
Henshall, H. BATTERIES FOR HIGH ALTITUDE APPLICATIONS. Inst. Radio Engrs. Can. Conv. Rec. p. 23-26, 1958.

Power sources available for high altitudes include dry cell, nickel cadmium batteries, and lead acid and silver oxide zinc batteries; one shot silver oxide zinc battery provides most power per unit weight and volume; nickel cadmium batteries are only ones that work well under cold temperatures. (Eng. Index p. 352, 1960)

2672
Hughes Aircraft Co., Culver City, Calif. REMOTELY ACTIVATED ZINC SILVER PEROXIDE RESERVE PRIMARY BATTERY, by E. E. Smith. 41p., illus., Aug. 30, 1954. (Tech. Memo. 352) (Contracts AF33(038)28634 and AF33(038)15826) (AD-47 115)

Activity was directed toward the development of a remotely activated reserve primary battery for use in applications where a considerable amount of power is required for one period of relatively short duration. In the battery developed and in those procured from 2 subcontractors, the electrolyte (KOH) is stored in a compartment separate from the one containing the plate and separator materials of the individual cells. The 2 compartments are so arranged that the electrolyte can be readily injected into the compartment containing the active plate and separator materials, thereby forming a battery which is charged and ready for use. All of the designs rely on a pressure differential to effect transmission of the electrolyte to the battery cell compartment. However, the 3 designs differ in the method of obtaining this pressure differential. Because these batteries do not require charging, the necessity of servicing during storage is obviated, even though the battery may be stored as long as 2 yr. The use of a reserve primary battery is expected to result in virtual elimination of all field handling and tactical problems associated with batteries.

2673
Mallory, P. R., and Co., Cleveland, Ohio. MAGNESIUM PRIMARY CELLS AND BATTERIES. Final Report, by C. G. Birdsall. 32p., Dec. 13, 1960. (Contract DA36-039-sc-73233)

Analysis of the development and production of various types of paperlined dry cells and battery packs, using magnesium cans.

2674
Naylor, D. PRIMARY CELLS. Contemp. Phys. 1:287-303, Apr. 1960.

The systems of the Leclanche, magnesium and R. M. (mercury) cells are described in detail, together with the lesser-known air depolarized and reserve type cells. Nuclear cells are still in the development stage and will be used for specialized applications only. Fuel cells are of great interest to the electrical engineer and a great deal of work has been done on this type of cell resulting in the recent production of a practical operating unit. (Sci. Abs. 64B:174, 1961)

2675
Ohio State University Research Foundation, Columbus, Ohio. IMPROVING PRIMARY BATTERIES, by A. B. Garrett. 5 issues, Oct. 1952, Jan. Mar. June, Sept. 1953. (Repts. 5, 6, 7, 8, 9) (Contract DA36-039-sc-222) (AD-3809, AD-3810, AD9342, AD-16 677, AD-21 183)

Investigations are reported of methods of increasing battery capacity at low temperatures; of electrochemical combinations of batteries for furnishing power at low temperature and for one-shot power supplies for high discharge-rate applications; of methods of increasing the shelf life; and of the fundamental properties of the materials used in batteries.

2676
Ohio State University Research Foundation, Columbus, Ohio. IMPROVING PRIMARY BATTERIES, by A. B. Garrett. 9 issues, 1953, 1954, 1955. (Repts. 1 through 8, and Final) (Contract DA36-039-sc-42603) (AD-21 182, AD-26 967, AD-31 475, AD-41 340, AD-64 434, AD-64 436, AD-68 422, AD-68 370, AD-83 219)

Conclusions are given to studies on use of manganese as an anode, fuel cells, and parameters that affect the magnesium anode at -30°C.

2677
Ohio State University, Research Foundation, Columbus, Ohio. IMPROVING PRIMARY BATTERIES, by A. B. Garrett. 8 issues, 1955, 1956, 1957. (Repts. 1-4, 6-9) (Contract DA36-039-sc-64561) (AD-83 217, AD-86 287, AD-93 188, AD-103 598, AD-114 792, Ad-124 218, AD-138 769, AD-156 961)

A resume of past experiments performed in the study of the magnesium anode delay action has been given. The study of the relation between the closed circuit voltage discharge curves and the open circuit emf curves of the magnesium anodes has been continued.

2678
Radio Corp. of America. Semiconductor and Materials Div., Somerville, N. J. HIGH CAPACITY MAGNESIUM BATTERIES, by G. S. Lozier, R. J. Ryan, et al. 4 issues, 1960, 1961. (Quart. Prog. Repts. 1, 2, 3, 4) (Contract DA36-039-sc-85340) (QPR-1, AD-254 456, QPR-2, AD-257 342)

The object of this research and development project is the development of high-capacity magnesium primary batteries using the perchlorate electrolyte systems.

2679
Radio Corp. of America. David Sarnoff Research Center, Princeton, N. J. PRIMARY CELLS UTILIZING ORGANIC COMPOUNDS AS THE ACTIVE COMPONENTS, by R. Glicksman, et al. 6 issues, 1958, 1959, 1960. (Quart. Repts. 1, 2, 3, 4, and 8 (Final)). (Contract DA36-039-sc-78048) (AD-206 646, AD-211 717, AD-217 258, AD-226 587, AD-229 118, AD-257 341)

The roles of carbon and water in the m-dinitrobenzene cathode, and the effect of magnesium efficiency upon cell performance are discussed. An evaluation of various cell configurations (round and flat) provides design criteria for optimum cell structures. The design of a practical flat cell is shown. A magnesium m-dinitrobenzene dry cell with a capacity of 90 watt-hours per pound is described.

A brief review of the theory concerning the effect of group type and

position in the molecule on cathode potential for the aromatic nitro and nitro alkane compounds, and its extension to heterocyclic nitro compounds and organic anode materials, is presented. The more important classes of organic anode materials, hydrazine, and organic cathode materials, nitropyridines, and nitrofurans, are discussed in greater detail.

2680
Schult, R. W. and Stafford, W. T. ELECTROCHEMICAL ENERGY SOURCES. NICKEL/CADMIUM BATTERIES. Electro-Tech. 68:87-91, figs., Jly. 1961.

This article, describing the properties, reactions, design, operation and mechanism of damage of nickel/cadmium batteries, is a followup of a preceding article (June 1961) on silver oxide/zinc batteries and the basic technology of galvanic power sources.

2681
Schult, R. W. and Stafford, W. T. ELECTROCHEMICAL ENERGY SOURCES. SILVER OXIDE/ZINC BATTERIES. Electro-Tech. 67:84-90, figs., June 1961.

A study of the characteristics and systems design of several types of galvanic power sources for missile and space-vehicle controls and components operation.

2682
Steier, H. P. SILVER-ZINC BATTERY MAY SOLVE SOME WEIGHT, SPACE PROBLEMS. Am. Aviat. 19:44-47, Mar. 12, 1956.

Yardney Silvercell is based on 150-year old system suggested by Volta and developed since World War I by French scientist Andre.

2683
Naval Research Laboratory, Washington, D. C. A BRIEF SURVEY OF VARIOUS SEA WATER CELLS, by T. P. Dirkse. 13p., illus., Nov. 1945. (Rept. P-2711) (AD-156 840)

A brief survey has been made of various types of primary cells which use sea water as the electrolyte. Several such cells were constructed, some of which were made in accordance with directions given in the literature. Of the combinations tried, the silver oxide-magnesium and cuprous chloride-magnesium cells gave the best results. These cells give a fairly steady voltage and this voltage does not change greatly with a decrease in temperature. With the cuprous chloride positives there is a dip in the discharge voltage curve immediately after the discharge begins. The silver oxide positives do not show this behavior. The silver chloride-magnesium cell also functions well with sea water but its discharge voltage is not as high as that of the silver oxide--magnesium cell and it requires twice as much silver for the same amount of electrical capacity. For a high rate cell a different system must be used. One system that is suggested consists of packing solid potassium hydroxide in a cell that has silver oxide positives and zinc plated screen negatives. This cell must be kept dry until ready for use, at which time the sea water is poured in.

2684
U.S. Naval Research Laboratory, Washington, D. C. THE SILVER OXIDE-ZINC ALKALINE PRIMARY CELL. Part IV. ANODIC CHARACTERISTICS OF ZINC ALLOYS, Interim Report by C. M. Shepherd. 19p., illus., Feb. 8, 1957. (Rept. 4885) (AD-123 429)

Preliminary work has been done on determining the capacity of the silver oxide-zinc alkaline cell when using various zinc alloys as a sheet anode. Most alloying elements decrease cell capacity, particularly if they are present in appreciable amounts. Mercury definitely improves cell capacity. A few other elements such as cobalt and calcium show some increased cell capacity but need further testing. The grain structure of electrodes made of zinc and its alloys has a large effect on cell capacity. Most

of the zinc alloys were found to roll better at very high temperatures.

2685
U.S. Naval Research Laboratory, Washington, D. C. THE SILVER OXIDE-ZINC ALKALINE PRIMARY CELL. PART V. COMPARISON OF POTASSIUM HYDROXIDE, CESIUM HYDROXIDE, AND RUBIDIUM HYDROXIDE ELECTROLYTES, by C. M. Shepherd and H. C. Langelan. 15p., figs., Jly. 25, 1961. (Rept. 5635)

All the discharges were made using high-purity, sheet-zinc negative electrodes. It was found that the cell capacity, within limits, is directly proportional to electrolyte volume, to electrolyte concentration, and to the amount of CsOH or RbOH present in the electrolyte.

At a given set of discharge conditions, the maximum capacity that could be obtained using CsOH or RbOH electrolytes was considerably less than could be obtained from KOH when compared on a weight basis. On a volume basis KOH was slightly better than CsOH or RbOH.

2686
U.S. Naval Research Laboratory, Washington, D. C. THEORETICAL DESIGN OF PRIMARY AND SECONDARY CELLS. Part I. EFFECT OF POLARIZATION AND INTERNAL RESISTANCE ON CURRENT DENSITY DISTRIBUTION, Interim Report by C. M. Shepherd. 57p., illus., Dec. 29, 1958. (Rept. 5211) (AD-216 803)

The current density distribution in an ideal cell is a function of the electrode height, the grid resistance, the electrolyte resistance, and the polarization. Mathematical solutions have been obtained for those cases where the polarization curves are either linear, logarithmic, cubic, or inverse cubic. A numerical method is indicated for finding a general solution. For practical applications, the use of the complex mathematical calculations involved has been eliminated by presenting the results in simplified graphs which show the current density distributions and other cell characteristics over a wide range of operating conditions. The determination of these cell characteristics can be of considerable importance in cell design.

2687
U.S. Naval Research Laboratory, Washington, D. C. THEORETICAL DESIGN OF PRIMARY AND SECONDARY CELLS. Part II. EFFECT OF POLARIZATION AND INTERNAL RESISTANCE ON CELL CHARACTERISTICS AND CELL DESIGN, by C. M. Shepherd. 26p., illus., Dec. 30, 1958. (Rept. 5212) (AD-214 825)

A study has been made of the effect of internal resistance on the current density distribution and the internal emf drop, E, in a cell. The current density distribution and E are mathematically related and both are a function of the dimensionless factor VH, where H is the electrode height and V is approximately the square root of the ratio of the unit grid resistance to the unit electrolyte resistance. When VH is high in value, there will be an uneven current density distribution in the cell which may be accompanied by a large number of undesirable effects. The term E represents that portion of the theoretical emf that cannot be utilized since it is converted to heat inside the cell. In many of the cells where VH is high, it would be desirable to reduce the values of the three factors: VH, E, and cell weight. It was found that any variation that could be made in any cell of standard structure and a given capacity could never reduce more than two of these factors and would also increase at least one of them. By going to unusual types of construction, it is possible to reduce all three of these factors simultaneously.

2688
Weininger, J. L. HALOGEN-ACTIVATED SOLID ELECTROLYTE CELL. Electrochem. Soc. J. 105: 439-441, 1958.

A new type of silver halide solid electrolyte cell consists of a small bead of silver halide with tantalum and silver wires, as the cathode and anode, respectively. The mechanism of the electrochemical reaction of this cell has been determined. When the cell is exposed to bromine or iodine vapor it is a promising primary cell for elevated temperatures. With silver iodide as electrolyte, the cell can be recharged several times.

2689
Weininger, J. L. IODINE-ACTIVATED SOLID ELECTROLYTE CELL FOR USE AT HIGH TEMPERATURE. Electrochem. Soc. J. 106:475-481, 1959.

Iodine-activated miniature cells, $Ta(I_2)/AgI/Ag$, with solid silver iodide as the electrolyte, have been studied at 150-550°. In this range of temperature, the cells have the following characteristics: complete conversion of the consumable silver anode into its electrical equivalent, open-circuit voltage of 0.67v., short-circuit currents up to 18 ma, capacity of 100 ma-hr, energy output up to 5 mw-hr/cell, a definite activation temperature obtained by selecting a suitable source of iodine vapor, and indefinitely long shelf life below that temperature. The size of the smallest cells is 0.15 cm in diameter and 0.5 cm in length.

C. Storage Cells

2690
Eagle-Picher Co., Joplin, Mo. RESEARCH INVESTIGATIONS LEADING TO THE DEVELOPMENT AND EVALUATION OF A CADMIUM-SILVER OXIDE BATTERY HAVING A HERMETICALLY SEALED CONSTRUCTION. 50p., Dec. 31, 1960. (Quart. Prog. Rept. 2) (Contract DA36-039-sc-85370)

During the quarter 700 shallow cycles were obtained from cadmium-silver-oxide sealed cells. The data obtained indicate that 0.040 ampere is the maximum continuous overcharge rate that can be applied to the cells of the present design.

2691
Eagle-Picher Co., Joplin, Mo. RESEARCH INVESTIGATIONS LEADING TO THE DEVELOPMENT AND EVALUATION OF A CADMIUM-SILVER OXIDE BATTERY HAVING A HERMETICALLY SEALED CONSTRUCTION, by J. Wilson. 14p., Mar. 31, 1961. (Quart. Prog. Rept. 3) (Contract DA36-039-sc-85370)

During this reporting period, several types of regenerated separator materials have become available for test, and some look quite promising at this time. Preliminary tests also indicate that negative plate developments have been made that will more than double the maximum allowable overcharge rate. Cycle life tests are under way, and capacity tests indicate that a longer cycle life will be obtained than in previous tests.

2692
Foote, H. L., Jr., Shair, R. C., and Smith, D. H. ELECTRICAL STORAGE OF SOLAR ENERGY. Mech. Eng. 81:40-43, diags., Jly. 1959.

Electrochemical phenomena offer the only technically feasible means of storage of solar energy for small stationary solar power plants. A large reduction in the cost of such devices is required for economic use.

2693
Gould-National Batteries, Inc., St. Paul, Minn. A KAPITZA TYPE NICKEL CADMIUM BATTERY. Final Report. 18p., n.d. (TID 11111) (Quart. Rept. 8) (Contract AT(30-1)-1831)

The life of individual test cells was very low when discharged to zero volts on each cycle, but addition of lithium to the electrolyte increased life to over 1000 cycles. The mechanism of lithium improvement of NiO_2 film stability is not known.

Equalizing cell capacities by overcharging was studied and it was found that a considerable overcharge improves poor cells faster than the good cells. (Nuclear Sci. Abs. 15:9029, 1961)

2694
Gould-National Batteries, Inc., St. Paul, Minn. A KAPITZA TYPE NICKEL CADMIUM BATTERY. Final Report. 9p., Mar. 15, 1958. (Rept. NYO-8643) (Contract AT (30-1)-1831)

A Kapitza type nickel-cadmium battery with the following characteristics was designed: number of plates, 10; size of plates, 35 by 35 cm; discharge time, -0.01 to 0.10 sec; life, more than 1000 cycles; and power output, -10 watts/sq cm. The cell design and materials of construction are given. (Nuclear Sci. Abs. 15:11175, 1961)

2695
Gulton Industries, Inc., Metuchen, N. J. INVESTIGATIONS LEADING TO THE DEVELOPMENT OF IMPROVED SEALED NICKEL-CADMIUM BATTERIES. 2 issues, Dec. 31, 1960, Mar. 31, 1961. (Quart. Prog, Repts. 2, 3) (Contract DA36-039-sc-85390)

Ceramic-to-metal seals are now produced consistently. The equipment for producing seals on the pilot plant level is being placed into operation. Accelerated testing of separator materials has been completed, and the properties of separators are reviewed. The promising separators now require testing in prototype cells. Six new separator materials were received during the last quarter and evaluation started. Overcharge data has been obtained on six cells. The data consists of the capacity, Tafel slope and pressure slope. Several cells with a ratio of negative to positive capacity near unity, were brought into several different states of charge. These cells were then pressured with oxygen and the pressure decrease obtained. This preliminary experiment will be repeated to confirm the data obtained. The question of oxygen adding capacity to a cell was investigated, and a negative answer obtained. The oxygen evolution data was analyzed on a phenomenological basis. The theory of the analysis was developed and is presented in the report. It appears that pure nickel has two sources of oxygen which have half-times of 9 and 102 minutes respectively. A third self-discharge process is also occuring, but no data has been obtained on this. The doped electrodes have two self-discharge processes which are suspected of being one oxygen source undergoing sequential decay. The potential decay data has been reported as the Tafel slopes.

2696
Hamer, W. J. AIRCRAFT STORAGE BATTERIES. Appl. & Indus. 50: 227-287, Sept. 1960.

Discusses in great detail the properties and characteristics of lead-acid, nickel-cadmium, and silver-zinc storage batteries, and indicates the features of each of these types which makes them suited to various application. (Index Aero. 17:69, Jan. 1961)

2697
Hamer, W. J. A REVIEW OF THE STATE OF THE ART AND FUTURE TRENDS IN ELECTROCHEMICAL BATTERY SYSTEMS. I. THE MORE COMMON SYSTEMS. In Seminar on Advanced Energy Sources, 1958. Proceedings... p. 41-54, Fort Monmouth, N. J., 1959? (Contract DA36-039-SC-78064) (PB 151461) (AD 209301)

Mentioned in some detail are: (1) secondary batteries (wet types)-lead-acid, nickel-iron, nickel-cadmium, zinc-silver-oxide, and aircraft; (2) secondary batteries (dry types)-energizer, hermetic, mercury and Leclanche type; (3) primary batteries (wet types)-standard, Lelande, and air cell; (4) primary batteries (dry types)-Leclanche, mercury, alkaline, air, and low-temperature cells; (5) reserve batteries - water-activated, chlorine, and perchloric

acid batteries, zinc-silver oxide, sodium, Pb-acid, Zn Pb and Cd-Pb, dry frozen, and thermal cells.

2698
IMPROVED BATTERY MEETS OUTER SPACE REQUIREMENTS. Electronics 34:110, 112, illus., Jan. 13, 1961.

Gives details of a rechargeable nickel-cadmium battery with a true hermetic seal. It may be used in conjunction with solar cells as a power source in satellites.

2699
Palágyi, T. Z. INVESTIGATION ON THE SILVER-ZINC STORAGE BATTERY WITH RADIOACTIVE Ag^{110} ISOTOPE. Electrochem. Soc. J. 108:904-906, Sept. 1961.

The results of experiments carried out with Zn^{65} isotope on the silver-zinc storage batteries were presented earlier. This paper describes results of investigations performed with Ag^{110} isotope.

2700
Schulman, I. M. SECONDARY BATTERIES FOR ENERGY STORAGE IN SPACE. In Snyder, N. W. ed. Energy Conversion for Space Power, p. 479-496, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3)

Certain problems associated with the design of batteries for space applications are discussed. Emphasis is placed on battery-charging problems when using the solar array for energy conversion. A thermal analysis is made for a battery which discharged 75% of its full capacity, and which is used for a vehicle in a 24 hour equatorial orbit.

Also issued as ARS Tech, Paper 1307-60. 21p., New York, American Rocket Society, 1960.

2701
Smith, H. R. NICKEL-CADMIUM BATTERIES. Convair Traveler 13:8-11, May 1961.

Discussion of the performance and maintenance of the 13.5 amp.-hr Sonotone nickel-cadmium storage battery in the Convair 880/990. Precautions to be observed in the handling of nickel-cadmium batteries are noted. (Intern. Aerospace Abs. 1:61-6293)

2702
Ulvönäs, S. ELECTRIC CELLS AND BATTERIES. Tek. Tid. 90:713-718, Aug. 5, 1960.

In Swedish. A review of new cell types with a view to their application in missiles and satellites. A table is given showing the main electrical characteristics as well as weight, volume and density for nine types of cell grouped under dry cells, mercury cells, air-depolarized cells, Ni-Cd accumulators, Ag-Zn accumulators and lead accumulators. (Sci. Abs. 64B:173, 1961)

VII. ENERGY STORAGE

A. General Information

2703
Landry, B. A. THE STORAGE OF HEAT AND ELECTRICITY. Natl. Acad. Sci. Proc. 47:1290-1296, Aug. 1961.

Numerous ways provided for the storing or releasing of heat energy are mentioned. Energy storage in connection with earth satellites is discussed and the concluding statement is made that "a great deal of research will be required before it can be decided, in terms of a given mission, whether generating and storage systems shall be electrical, thermal, or a combination of the two."

2704
Voysey, R. G. THE STORAGE OF ENERGY. Eng. 186:380-382, Sept. 19, 1958.

Discussed are: early concepts, classification, storage forms, resilient materials, electrical forms, batteries, fuel cells,

meeting peak loads, pumped storage, and underground storage.

2705
Winkler, S. H. OPTIMUM DESIGN OF A SPACE VEHICLE STORAGE SYSTEM. In Power Sources Conference. Proceedings, 14th, p. 90-93, Red Bank, N. J., PSC Publications Committee, 1960.

The discussion is concerned with the design of storage systems the requirement for which is that they may be charged in the daytime and deliver energy at night.

B. Chemical

2706
Bacon, F. T. ENERGY STORAGE BASED ON ELECTROLYZERS AND HYDROGEN/OXYGEN FUEL CELLS. 12p., New York, United Nations, May 6, 1961. (E/CONF 35/GEN/9)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

Where electricity is being generated from wind-driven generators or from solar energy, it becomes desirable to incorporate some storage device, and it has been suggested that the combination of electrolysers and hydrogen/oxygen fuel cells could provide this need. An admittedly far from complete analysis is given for the purpose of inviting suggestions and criticism.

2707
Marcus, R. J. PHOTOCHEMICAL CONVERSION REACTIONS AND THE STORAGE OF ENERGY AS HYDROGEN. In Conference on the use of Solar Energy: The Scientific Basis, Tucson, 1955. Transactions, vl. 4, p. 175-181, Tucson, University of Arizona, 1958.

Several photochemical means of producing hydrogen are considered from the point of view of their practicality. The difficulties are pointed out.

2708
Stephens, C. W. and Ludwig, F. A. ENERGY STORAGE DEVICES. In Power Sources Conference. Proceedings, 14th, p. 97-99, Red Bank, N. J., PSC Publications Committee, 1960.

Some thermal storage systems are considered and the most pressing problems are delineated. This is followed by a comparison between thermal and electrical storage in a solar thermal system.

2709
Werner, R. C. and Ciarlariello, T. A. METAL HYDRIDE FUEL CELLS AS ENERGY STORAGE DEVICES. 12p., charts, New York, United Nations, May 23, 1961. (E/CONF. 35/GEN/14)

The present state of development of metal hydride cells is discussed and the concept is considered of such devices receiving energy from the sun, converting the energy into stored chemical energy and continuously producing electrical energy. Comparison to other conversion and storage devices is limited because of the still early development stage of the subject devices.

The process of thermally decomposing the reaction products to form the fuel and oxidizer required by the fuel cell makes the unit both an energy storage and an energy conversion device.

C. Electromagnetic

2710
Clampitt, B. H. and German, D. E. NEW ENERGY-STORING DEVICE PROMISES EFFICIENT SOLAR-TO-ELECTRIC ENERGY CONVERSION. Soc. Automotive Engrs. J. 68:52-55, illus., May 1960.

Measured potentials of experimental cells are low, but warrant further consideration. Research to reduce high internal resistance should pay off in higher maximum power per unit electrode area.

D. Mechanical

2711
Roes, J. B. AN ELECTRO-MECHANICAL ENERGY STORAGE SYSTEM FOR SPACE APPLICATION. In Snyder, N. W. ed. Energy Conversion for Space Power, p. 613-622, illus., New York, Academic Press, 1961.

This paper discusses a mechanical energy storage system and describes the characteristics of a typical example for space application which stores energy in two magnetically suspended fly-wheels. The system converts electrical energy into mechanical energy for storage and, after storage, reconverts it for use in the load.

VIII. ENERGY SOURCES

A. General Information

2712
Anderson, G. M. MORE ELECTRICAL POWER FOR SPACE VEHICLES. Aircraft & Missiles 4:23-27, illus., May 1961.

AEC's SNAP units pack isotope- and reactor-type generators; SNAP-10 reactor will develop 300 w for a weight of 620 lb; abundant electricity promised for power-starved satellites.

2713
LeChatelier, Jean. PETROLEUM AND URANIUM AS POWER SOURCES. En. Nucleaire 3:101-109, Mar/Apr. 1961.

In French. Uses of conventional and nuclear energy are compared. Future uses of nuclear power may include direct heat production, electricity production with high load factors, and ship propulsion. It is noted that petroleum and uranium uses in the future must be coordinated. (Nuclear Sci. Abs. 15:19091, 1961)

B. Chemical Fuels

2714
National Advisory Committee for Aeronautics, Washington, D. C. PRELIMINARY SURVEY OF PROPULSION USING CHEMICAL ENERGY STORED IN THE UPPER ATMOSPHERE, by L. V. Baldwin and P. L. Blackshear. 73p., May 1958. (Tech. Note 4267)

This report presents a preliminary study of a ramjet that would use the chemical energy of dissociated molecules in the ionosphere for propulsion. A review of the physical properties and chemical composition of the upper atmosphere shows that the available energy is not sufficient for flight requiring aerodynamic lift. Above 300,000 feet, dissociation energy might be useful for satellite-sustaining.

2715
Stanford University Research Institute, Menlo Park, Calif. THE HILL REACTION AS A MODEL FOR CHEMICAL CONVERSION OF SOLAR ENERGY, by R. J. Marcus. 9p., Dec. 1, 1959. (Tech. Rept. 15) (AFOSR-TR-59-208) (Contract AF18(603)07) (PB161 462)

The possibility of storing solar energy for use during dark periods by decomposition of water into its elements was explored along two lines. One of these consisted of taking advantage of the electron transfer spectra of inorganic ions. These were surveyed and listed, together with chemical and thermodynamic correlative data. The other method consisted of a study of various Hill reaction oxidants. Two new electron acceptors, $Co(C_2O_4)_3^{-3}$ and Cr^{+3}, were found to be active in the Hill reaction.

C. Nuclear

2716
Chapman, R. A. SAFETY OF DIRECT CONVERSION, NUCLEAR FUEL ELEMENTS UNDERGOING RAPID EXPONENTIAL POWER EXCURSIONS. Am. Nuclear Soc. Trans. 4:39, June 1961.

Abstract of paper given at the 1961 annual meeting of the American

Nuclear Society, Pittsburgh, Pa., June 4-8, 1961.

The transient temperature response of slab or cylindrical thermoelectric direct conversion nuclear fuel elements to short (0.100 to 0.005 sec) positive exponential periods in the thermal power has been analyzed using the safety criteria of Golian, et al. The results show that safety must rely on a negative temperature coefficient of reactivity in the fuel. For exponential periods greater than 0.025 sec, consideration of convective cooling would strengthen the conclusions.

There are two ways to combine direct conversion generators and nuclear reactors: one design places the generator in the external heat exchanger; the other design places the generators between each fuel element and the coolant. The latter design is considered here.

2717
Corliss, W. R. CURRENT DEVELOPMENTS IN COMPACT NUCLEAR SYSTEMS. In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p.51-56, New York, American Institute of Electrical Engineers, Dec. 1960.

Radioisotope and fission types of heat sources are discussed.

2718
DIRECT-INDIRECT NUCLEAR ENGINE CHOICE AWAITS TEST DATA. Aviat. Wk. 73(26):40-59, 1960.

It is estimated that at least another two years development and tests will be required to provide sufficient data for comparing the direct and indirect systems. The principal development problem of the former is design of an advanced type of reactor. For the indirect plant, the heat exchange system is a major problem. Current developments of these aspects are discussed.

2719
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume X, REACTOR SYSTEM DESIGN. 125p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. X) (Contract AF33(616)6791) (AD-256 884)

Discusses various aspects of reactor design with respect to inherent limitations and system requirements and outlines many problems common to all nuclear systems, such as shielding, reliability, heat rejection, and safety.

2720
Hagis, W., Dobry, T., and Dix, G. NUCLEAR SAFETY ANALYSIS OF SNAP 3. FOR SPACE MISSIONS. ARS Tech. Paper 142--60, 12p., 1960.

SNAP-3 is an auxiliary power unit which converts the decay heat from radioisotope fuel into electrical power. Results are summarized of a study of the propagation of radiation from the fuel in case of post-orbital re-entry or an abort. Possible locations of impact were plotted. The effects of aerodynamic heating on the formation of radiopolonium aerosol were studied. Results indicate that SNAP-3 would be acceptable for operational missions. (Index Aero. 17:118, 1961)

2721
Koerner, T. W. and Paulson, J. J. NUCLEAR ELECTRIC POWER FOR SPACE MISSIONS. IAS, Annual Meeting, 29th, New York, Jan. 23-25, 1961. Paper 61-66, 26p. Also in Aerospace Eng. 20:18-19, 44-46, 48-49, May 1961.

Study considering nuclear electric power, applications for planetary, interplanetary and lunar exploration, for secondary power requirements, and for the final phases of propulsion to place a spacecraft at its destination. Radioisotope thermoelectric generators are considered most suitable for use where a small amount of power for an

extended period is required. Of the numerous applications of electric propulsion in spacecraft, this investigation considers only the propulsion necessary to take a spacecraft from an earth orbit and place it at a more distant destination in space. Four such missions are considered, in which electric propulsion is compared with chemical systems. Tables are presented from which the conclusion is drawn that, in numerous cases, electric systems appear to give a significant advantage. (Intern. Aerospace Abs. 1:61-2624, Apr. 1961)

2722
Linhart, J. G. SOME CRITERIA FOR THE DIRECT TRANSFORMATION OF NUCLEAR ENERGY INTO ELECTRICITY. Atom u. Strom 6:83-85, Sept. 1960.

In German. The characteristics of a thermonuclear reaction that could be used for direct transformation into electrical energy are briefly described. (Nuclear Sci. Abs. 15:3549, 1961)

2723
Mayer, F. PERSPECTIVES FOR THE USE OF NUCLEAR POWER IN AVIATION. Aerotecnica 40:287-298, Oct. 1960.

In Italian. Discusses "direct-cycle" and "intermediate heat-transfer systems," also temperature requirements and shielding systems. (Index Aero. 17:65, Mar. 1961)

2724
Miller, P. H., Jr. NUCLEAR ENERGY MECHANISMS. In Seminar on Advanced Energy Sources, 1958. Proceedings... p. 35-41, Fort Monmouth, N. J., 1959? (Contract DA-36-039-SC-78064) (PB 151461) (AD 209301)

A description of the basic nature of nuclear phenomena and a prophesy that the space ships which will go to the stars will use anti-protons as their source of energy.

2725
National Aeronautics and Space Administration, Washington, D. C. FOURTH SEMIANNUAL REPORT TO CONGRESS, 1 April THROUGH 30 September 1960. 1 vl. illus., Sept. 30, 1960. (AD-252 376)

Contents include information on propulsion and nuclear energy applications for space.

2726
Naymark, Sherman. NUCLEAR POWERPLANTS FOR SPACE-VEHICLE APPLICATION. In American Astronautical Society. Advances in the Aeronautical Sciences. Proceedings, 6th, New York City, 1960, p. 643-658, New York, Macmillan, 1961.

This paper addresses itself basically to the potential place of nuclear energy powerplants for space power applications and to their advantages or disadvantages as compared with other types of power-plants.

2727
Polling, J. J. ELECTRICITY FROM THE ATOM. Discovery 17:111-114, illus., Mar. 1956.

The development of direct-charging devices is traced through inventions of the past few years.

2728
Treco, R. M. HOW SPACE-AGE ENERGY SOURCES SPARK RISE OF NEW MATERIALS. Iron Age 187: 87-89, Mar. 2, 1961.

Problem of power plants for space vehicles discussed; nuclear energy appears to be the answer when power levels higher than 10 kw for 10-100 hr are needed. Three cooling methods for nose cone are now under study; other critical areas in rockets and missiles are noted and materials considered. Problem of radiation and high-temperatures when using nuclear power stations and efficiencies of energy conversion devices are discussed.

2729
U.S. Signal Corps Engineering Laboratories, Evans Signal Laboratory, Belmar, N. J. SECONDARY-EMISSION NUCLEAR BATTERY, by Erich Schwarz. 1 vl., illus., Apr. 15, 1955. (Tech. Memo. M-1644) (AD-66 176)

The basic considerations pertinent to the conversion of nuclear energy into electric power are presented with emphasis upon development of portable nuclear batteries. Operation and properties of the recently developed types are discussed, and summarized in tabular form. A new type of nuclear battery is described which utilizes secondary electron emission. Its main feature is a stable operating potential of a few volts per cell which cannot be achieved by other known types. A principal design for the secondary-emission nuclear battery is explained and treated mathematically. The efficiency of this model is estimated to be greater than that of any previous type when a very weak beta emitter such as tritium is used for the source. For a high-energy beta emitter such as strontium-90, the efficiency drops drastically. Five modifications of the secondary-emission nuclear battery are also outlined. One of them which incorporates a multiple arrangement of secondary emitters offers a way to overcome the efficiency drop at high beta energies. Finally, a program for the investigation and construction of the secondary-emission nuclear battery is proposed.

2730
Van Dong, Nguyen. THE DIRECT CONVERSION OF NUCLEAR ENERGY TO ELECTRICAL ENERGY. Bull. Info. Sci. et Tech. (Paris) no. 41, p. 14-27, June 1960.

In French. The methods for the conversion of nuclear energy into electrical energy are radioactive p-n junction cells, thermoelectric phenomena in semiconductors, and the thermoelectric effect in metals. Each of these methods is described, and the electric power and conversion yield are studied. (Nuclear Sci. Abs. 14:26093, 1960)

1. General Information

2. Isotopes

2731
Beller, William. 'BOTTOM BOUNCE' TESTS WILL BE FIRST AT AUTEC. Missiles & Rockets 9:40-41, illus., Oct. 23, 1961.

Nuclear fuel is one of several power sources under consideration for the fixed underseas stations to be utilized in connection with the "acoustic plumbing" of the depths of the Navy's underwater range for basic sonar data.

2732
Booda, Larry. TRANSIT, TWO SMALL SATELLITES WORK DESPITE MALFUNCTION. Aviat. Wk. 75:26-28, illus., Jly. 10, 1961.

A news story about the first satellite to carry an atomic auxiliary power unit gives some details of the Snap 3 unit.

2733
Coleman, J. H. ISOTOPE DEVICES PRODUCING ELECTRICAL ENERGY. In Seminar on Advanced Energy Sources, 1958, Proceedings...p. 158-164, Fort Monmouth, N. J. 1959? (Contract DA-36-039-sc-78064) (PB 151461) (AD209301)

Principles of operation of existing isotope power sources are described and this background used to suggest isotope generator structures for outer space.

2734
Crane, W. W. T. SPACE POWER. In International Astronautical Congress, London, 1959. Proceedings, vl. 2, p. 748-755, illus., Wien, Springer Verlag, 1960.

Recent research and test data are described which indicate so far that

a safe, reliable and practical radioisotope-fueled auxiliary power supply can be built using existing technology.

2735
DESIGN AND CONSTRUCTION FEATURES OF A NUCLEAR-POWERED CELL. Electron. Equip. 5:26-27, Mar. 1957.

Power source for the cell which is said to offer great potential for subminiaturization, is the decay energy of a beta-emitting radioisotope.

2736
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume XI, RADIOISOTOPE SYSTEM DESIGN. 316p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. XI) (Contract AF33(616)6791) (AD-256 916) (PB 171 868)

Describes technology, radiation safety, and design of isotope fueled auxiliary power generators for space use.

2737
FINDING WAYS TO POWER SATELLITES. Bus. Wk. p. 118-119, illus., Jly. 22, 1961.

NASA's highly successful Transit IV-A gets its electricity from atomic reaction. It is an important milestone in the development of reliable energy to power spacecraft.

2738
Gettings, Hal. SNAP SUCCEEDS ON TRANSIT...ERA OF NUCLEAR SPACE APU'S ARRIVES. Missiles & Rockets 9:12-13, illus., Jly. 10, 1961.

This is a general news article about the launching of TRANSIT IV-A which carried a SNAP unit to furnish power for some of the satellite instrumentation as well as that for two transmitters. The first signals from the satellite came, it is reported, from the nuclear-powered transmitters.

2739
Harvey, Douglas. ISOTOPIC HEAT AND POWER. In American Power Conference, Proceedings, Mar. 29-31, 1960, Chicago, Ill., vl. 22, p. 68-77, Chicago, Illinois Institute of Technology Press, 1960.

A survey on radioisotopes as self-contained sources of power is presented in which some of the factors involved in radioisotopic power source design and some of their possible applications are described.

2740
Harvey, R. J. and Hatsopoulos, G. N. ISOTOPIC FUELED THERMIONIC GENERATORS. In Symposium on Ballistic Missile and Space Technology, 5th, Los Angeles, Calif. Aug. 1960. Proceedings Propulsion and Auxiliary Power Systems, ed. by D. P. LeGalley, p. 409-441, illus., New York, Academic Press, 1960. (Ballistic Missile and Space Technology, vl. 2)

Progress of the thermionic generator phase in the SNAP-3 program is outlined.

2741
Linder, E. G. and Christian, S. M. THE USE OF RADIOACTIVE MATERIAL FOR THE GENERATION OF HIGH VOLTAGE. J. Appl. Phys. 23:1213-1216, figs., Nov. 1952.

An investigation has been made of the use of beta-emissive radioisotopes for generating high voltages. Voltage was obtained by supporting a beta-emitter on an insulated electrode in a low-pressure gas and allowing it to charge itself by virtue of its electron emission. This method represents a direct conversion of nuclear energy into electrical energy. The apparatus is described. Data on insulation breakdown, the effect of gas pressure, and the electrode material are given. The maximum voltage was obtained at a pressure of 10^{-3} mm of Hg. The electrical characteristics of such a generator are discussed. Using an emitter containing 0.25 curie of strontium 90,

a voltage of 365 kilovolts was obtained.

2742
McHugh, L. C. UNUSUAL SATELLITE: TRANSIT IV-A America 105:574, 576, Jly. 29, 1961.

Concerns the use, for the first time, of an atomic battery in a satellite. The little "gadget" is "a late model of the radioisotope-fueled thermoelectric generator" demonstrated in 1959.

2743
Martin Co. Nuclear Division, Baltimore, Md. CONCEPTUAL DESIGN OF A SNAP III TYPE GENERATOR FUELED WITH CERIUM-144. 46p., Jun. 1960. (Rept. P-2369) (Contract AT(30-3)-217)

This system will provide a low-power electrical source utilizing a thoroughly tested and proven thermoelectric generator. A major conclusion derived from the study of a cerium fueled system is that its specific power is not competitive with other systems in its power range when a mercury shield is used.

2744
Martin Co., Nuclear Division, Baltimore, Md. THE FEASIBILITY OF PRODUCING POWER FROM RADIOISOTOPES, by F. Hittman. 12p., 1957. (Rept. P-1031)

An address presented before the American Nuclear Society Annual Meeting, Pittsburgh, Pa., June 10-15, 1957.

Power-producing capabilities, cost, and availability of several radioisotopes are discussed.

2745
Martin Co. Nuclear Division, Baltimore, Md. FUEL TECHNOLOGY DEVELOPMENT PROGRAM. 2 issues, Mar. 31, Jun. 30, 1961. (Repts. P-3014-III, P-3015-III) (Quart, Prog. Repts. 6, 7 (Task 6))

The work covered is divided as follows: general development and materials requirements; americium-curium radioisotope preparation processes; radioisotope fuel form development; safety, shielding and thermal analyses; and irradiation of americium.

It is stated that "during this report period, the Task 6 Program made several noteworthy accomplishments towards the ultimate development of isotope power sources for thermoelectric and thermionic conversion to electrical energy."

2746
Martin Co. Nuclear Division, Baltimore, Md. PRELIMINARY OPERATIONAL SAFETY REPORT FOR THE TASK 5.6 THERMOELECTRIC GENERATOR. 51p., May 1960. (Rept. P-2356)

This report evaluates the operational hazards associated with the use of a plutonium-fueled thermoelectric generator in a terrestrial satellite.

2747
Martin Co. Nuclear Division, Baltimore, Md. SNAP PROGRAMS. 112p., Dec. 31, 1960. (Rept. P-3013-II) (Quart. Prog. Rept. 5)

An appraisal of work of the thermionic isotopic power systems (SNAP-TIP systems) and Task 6, Fuel Technology Development Program.

2748
Martin Co. Nuclear Division, Baltimore, Md. SNAP PROGRAMS. TASK 8 - STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR DEVELOPMENT. 78p., June 1961. (Rept. P-2483-1) (Quart. Prog. Rept. 1)

Pertinent details are given of the 10-watt thermoelectric generator which is the basic component of both the SNAP-7A and 7C power systems. Factors considered are generator description, isotope fuel, safety and shielding, thermoelectric

elements, and manufacturing drawings and weights.

2749
Martin Co. Nuclear Division, Baltimore, Md. SNAP PROGRAM. TASK 8. STRONTIUM-90 FUELED THERMOELECTRIC GENERATOR DEVELOPMENT. 1/2 in. thick, Apr. 30, 1961. (Rept. P-2483-2) (Quart. Prog. Rept. 2)

The current effort involves the design and engineering analysis of the SNAP-7 thermoelectric generators. Fuel process flow and associated equipment requirements for remote conversion of Strontium-90 feed material to strontium titanate pellets are covered.

2750
Martin Co. Nuclear Division, Baltimore, Md. SNAP RADIOISOTOPE SPACE PROGRAMS. 3 issues, Dec. 1960, Mar., June 1961. (Repts. P-3013-I, P-3014-I, P-3015-I) (Quart. Prog. Repts. 5, 6, 7)

Describes SNAP-1A and SNAP-3 thermoelectric generator development and also the radioisotope safety programs conducted.

2751
Martin Co. Nuclear Division, Baltimore, Md. STRONTIUM-90 POWER PROJECT. 90p., Apr. 1959. (Rept. SR-1673) (Quart. Prog. Rept. 2) (Contract AT(30-1) 2281)

The purpose of this program is to determine the feasibility of using Sr^{90} as the heat source in a thermoelectric generator which is to have an unattended life expectancy of up to 10 years under the most extreme environmental conditions. Designs for 100-w generators for land, sea, and undersea applications are being developed.

2752
Martin Co. Nuclear Division, Baltimore, Md. THERMIONIC ISOTOPIC POWER SYSTEMS. 2 issues, Mar. 31, June 30, 1961. (Repts. P-3014-II, P-3015-II) (Quart. Prog. Repts. 6, 7)

Cesium-diode generator development, vacuum diode generator, and the curium fuel capsule are subjects covered.

2753
MINIATURE NUCLEAR-POWERED BATTERY PACKS FIVE-YEAR PUNCH. Indus. Labs. 8:82-83, illus., Apr. 1957.

Concerns battery developed by the Elgin Watch Company which depends on a two-step conversion of energy: from beta emissions to light and from light to electricity.

2754
MORE ELECTRICAL POWER FOR SPACE. Aircraft & Missiles 4:23-29, May 1961.

AEC's SNAP units pack isotope and reactor-type generators and promise abundant electricity for power-starved satellites.

2755
NUCLEAR BATTERY POWERS WEATHER TRANSMITTER. Sci. News Ltr. 80·37, Jly. 15, 1961.

A brief item describes the weather station's five-watt battery powered by radioactive strontium titanate. It will not need any maintenance and will last for ten years, making it well suited for isolated locations like the North Pole.

2756
NUCLEAR-THERMOELECTRIC GENERATOR DEVELOPED. Elec. Eng. 80:392, May 1961.

Refers to a completely portable nuclear auxiliary power device, which weighs less than 40 pounds, produces approximately 150 watts of electric power and is designed for one year of continuous unattended operation. It uses radioactive isotopes, such as Curium 242 as its

heat source. It is designated the NAP-100.

2757
Ogburn, G. H., Jr. NUCLEAR ENERGY POWER SOURCES. In Power Sources Conference, Proceedings, 14th, 1960 p. 12-18, Red Bank, N. J., PS Publications Committee, 1960.

The applications of small lightweight nuclear power sources for operation without maintenance for long periods of time in remote areas are discussed. Such sources cost and weigh less than conventional chemical batteries. The SNAP program, which is developing several devices under 1 kw(e) output, is described. SNAP 10 is a reactor energy source giving 0.3 Mw(e) output from U^{235}-Zr hydride fuel, and is a static compact unit with no cooling system. Some of the possible isotopes for use in radioisotope energy sources and their characteristics are given. SNAP III is fueled by Po^{210} whereas SNAP 1A is fueled by Ce^{144} and is designed for use in space. Other radioisotopic units being developed are briefly described, e.g., thermionic units and units utilizing a long-lived radioisotope (Sr^{90}). (Nuclear Sci. Abs. 15:11863, 1961)

2758
RADIO ISOTOPIC POWER WILL BE USED TO OPERATE AN UNDERWATER SEISMOGRAPHIC STATION. Chem. Wk. 89:99, Aug. 5, 1961.

"The Atomic Energy Commission's Office of Isotope Development, Columbus University's Geographical Laboratory and Royal Research Corp. (Dublin, Calif.) are cooperating on a project that will place a 5-watt, cesium-137 generator on the ocean floor (2,500-3,000 fathoms below the surface) somewhere south of Bermuda. Work on fabrication of the generator started last month; it's scheduled for delivery in December and the station should start operating soon afterward.

"Heat from the cesium-137 will be converted into electricity in lead telluride thermocouples at an overall efficiency of 7% or greater. If the project proves out, the use of similar generators will probably get a tryout for other underwater work such as antisubmarine devices, nuclear explosion detectors, and repeater generators for transoceanic cables. Reason: the sea is an ideal environment for isotopic power, offering a natural shield and incomparable heat sink." Entire item Quoted.

2759
Royal Research Corp., Hayward, Calif. THE CESIUM-137 POWER PROGRAM. 80 p., Apr. 1961. (Rept. CS-0100) (Quart. Prog. Rept. 1) (Contract AT(04-3)-366)

The preparation of a chemical form of cesium with high cesium content, insolubility in aqueous media, and other desirable characteristics for use as generator fuel material was investigated. The materials studied included cesium silico-tungstate, cesium-enriched kaolin clay, cesium-enriched kaolin sand, and cesium-enriched complex borosilicates. Data are presented for the efficiency of a Westinghouse thermoelectric couple as a function of cold junction temperature.

2760
THERMOELECTRIC POWER FROM THE ATOM -- PROSPECTS GOOD. Mach. Design 32:23, Mar. 3, 1960.

S. J. Angello of Westinghouse predicts that rare-earth metals will soon boost operating limits of thermoelectric systems in which case nuclear heat temperatures will become useful in power generation. Dr. P. C. Aebersold, AEC's isotope development director, points out that a thermoelectric system powered by decay of strontium 90 radio isotopes will go into operation at Oak Ridge within a year. It will generate up to 100 watts and use about 5% of the strontium^{90} emission. The output from the 340 pound thermoelectric system will compare favorably with the output from 125 tons of chemical storage batteries.

2761
U. S. Air Force. Rome Air Development Center, Griffiss Air Force Base, New York. PERFORMANCE OF THE TAP-100 THERMOELECTRIC CONVERTER, by J. E. McCormick. 14 p., illus. Apr. 1961. (RADC-TN-61-26) (AD 257312)

The device was operated to failure with the test program being divided into three parts as follows: (1) a preliminary evaluation during which a number of short runs were conducted so that loading and fuel consumption data could be obtained for various hot junction temperature levels; (2) a life test of the device; and (3) final testing, conducted just prior to disassembly. After testing the device was disassembled and the failure mechanics analyzed. Results indicated failure was caused by a combination of numerous internal shorts and severe junction break-down.

3. Fission Reactors

2762
Aerojet-General Corp., Azusa, Calif. DEVELOPMENT OF SNAP-8 NUCLEAR POWER CONVERSION SYSTEM MODEL AGAN-0010. 69 p., figs., Apr. 1961. (Rept. 039-04-3) (Contract NAS 5-417)

This is a report of accomplishments for a program, the objective of which is the design and development of two 30-kw electrical generating systems for use in various space missions. Power source will be a nuclear reactor.

2763
Atomics International, Canoga Park, Calif. DC ELECTROMAGNETIC PUMP STUDY FOR THERMIONIC CONVERSION REACTORS, by W. J. Fraser. 10 p., Jly. 15, 1960. (NAA Rept. SR-Memo-5501)

The design of a d-c conduction electromagnetic pump for pumping sodium at 1300°F at a rate of 175 gpm with a developed pressure of 15 psi is reported. The maximum conduction current available was 1000 amp. Computations show that a pump meeting the requirements weighs 552 lb and has an efficiency of 19%. A voltage of 6.1 volts is required at the pump. Owing to the limitation of conduction current available, it is necessary to use ten pumping sections in series. (Nuclear Sci. Abs. 15:8265, 1961)

2764
Bickerton, R. J., and Jukes, J. D. THE DIRECT CONVERSION OF THERMONUCLEAR ENERGY TO ELECTRICAL POWER IN THE STABILIZED PINCH. J. Nuclear En. 8:206-214, 1959.

A method is suggested whereby the energy liberated by the thermonuclear reactions in a stabilized pinched discharge may be converted directly into electrical power. Physical criteria are derived which must be satisfied by the discharge. A comparison is made between the direct conversion method and one in which an external heat cycle is used.

2765
Gardner, J. W. ELECTRIC POWER FROM NUCLEAR HEAT - DIRECTLY Nuclear En. p. 237-242, June 1961.

The direct conversion of the heat in nuclear fission into electric power without the intermediary of turbine or other moving parts has already been demonstrated on a laboratory scale. This article reviews the thermionic converter and thermoelectric converter which appear to be the two most promising methods.

2766
General Electric Co. Knolls Atomic Power Laboratory, Schenectady, N. Y. COMPACT REACTOR POWER PLANT WITH COMBINATION HEAT EXCHANGER-THERMOELECTRIC PUMP, by E. A. Luebke and L. B. Vandenberg. 19 p., Jly. 7, 1954. (Rept. 1144(del.)) (Contract W31-109-eng-52)

A compact reactor power plant is described in which the reactor proper

is located within a cylindrical heat exchanger. The pumping action in the liquid-metal-cooled system is obtained in combination with the heat exchanger function. By interposing thermoelements, a large thermoelectric current is generated in the heat exchanger by the temperature gradient normally existing between hot and cold tubes. With suitable pole pieces, the current produces a perpendicular magnetic field and develops sufficient force on the liquid metal for the desired pumping action. (Nuclear Sci. Abs. 15:19031, 1961)

2767
Rosenblum, Louis and English, R. E. NUCLEAR-ELECTRIC SYSTEMS IN SPACE. In Seminar on Advanced Energy Sources, 1958. Proceedings ...p. 243-253, Fort Monmouth. N. J., 1959? (Contract DA36-039-78064) (PB 151461) (AD 209301)

Ideas and thoughts are presented on the role of the radiator in space power systems, nuclear turboelectric systems, and nuclear-thermionic emitters.

2768
Westinghouse Electric Corp., Pittsburgh, Pa. 3MW(e) NUCLEAR THERMOELECTRIC POWER PLANT PROGRESS REPORT, May-August 1960, by R. A. Clark, Jr., R. A. Doncals, and R. R. Holman. 73 p., 1960. (Rept. WANL-PR(A)001) (Contract Nonr-3216(00))

The reference thermoelectric generator element was selected as one that will give an overall conversion efficiency of 7% for a practical generator, including allowance for contact losses and other assembly degradations.

Tentative design information indicating summary performance capabilities currently considered feasible is listed.

4. Fusion

2769
Hoyaux, M. RECENT PROGRESS IN NUCLEAR FUSION AND FUTURE PROSPECTS. Assoc. Ing. Elec. Sortis de l'Inst. Electrotech. MonteFlore. Bull. 73:449-479, Jly/Aug. 1960.

In French. The paper presents up-to-date data on controlled thermonuclear reactions, stability conditions of magnetic containment, and their incidence on critical temperature. A possible reactor is described which should be capable of transforming thermonuclear energy directly into electricity. A brief summary is given of various approaches now under consideration: magnetic pinch, stellarator and magnetic mirror machine. It is suggested that fusion should be technically feasible toward the end of the century but should only undergo important developments during the next century. (Fuel Abs. & Current Titles 2:340, Jan. 1961)

2770
Jukes, J. D. POSSIBILITIES OF DIRECT ENERGY CONVERSION FROM FUSION REACTORS. Inst. Elec. Engrs. Proc. 106A:173-176, Apr. 1959.

Method whereby 1/3 of available energy in fusion reactors may be directly extracted as electrical energy. By comparison with indirect conversion of fission reactors, advantage is high thermodynamic efficiency and elimination of intermediate heat exchange equipment. Net power reactor requires squarely modulated current of several million amp for deuterium-tritium mixtures. (Eng. Index p. 900, 1960)

2771
Maslen, S. H. FUSION FOR SPACE PROPULSION. Inst. Radio Engrs. Trans. MIL-3:52-57, Apr. 1959.

The possible role of a controlled thermonuclear reactor in space missions is discussed. Although such a reactor is many years from reality, some of its properties are understood well enough to indicate problems which will appear and which are peculiar to space flight. It appears that it will have to deliver electric power or thrust at a weight of about

one pound per kw in order to represent significant improvement over other systems, notably the fission-electric one. One attractive feature of a fusion reactor, as now envisioned, is that it may lend itself to the direct production of electricity or even thrust, without an intermediate heat cycle. It is essential to avoid such a cycle if the weight is to be kept low.

2772
Slepian, Joseph. THE IONIC CENTRIFUGE AND FUSION NUCLEAR POWER. Natl. Acad. Sci. Proc. 47:313-319, Mar. 1961.

The Ionic Centrifuge is briefly described. The discharge in this device violates the usual rules of magnetohydrodynamics because of the high electric field parallel to the magnetic field in the space charge affected boundaries. The kinetic energy of random motion of the particles is proportional to the voltage which the main discharge holds at each point. By causing this voltage to rise to a high positive value and then drop to zero at the cylinder, the ions are not collected when their kinetic energy is high, but only at the cylinder where this kinetic energy is low again. The suitability of this arrangement for nuclear power converters is pointed out. (Nuclear Sci. Abs. 15:15161, 1961)

D. Solar Collection and Concentration

2773
Blumrich, J. F. SOLAR ENERGY CONCENTRATORS. In Power Sources Conference. Proceedings, 14th, 1960, p. 18-21, Red Bank, N. J., PSC Publications Committee, 1960.

Concerns a study of concentration of solar energy effected by mirrors of a variety of shapes, materials and design approaches, with the goal of weight optimization and actual hardware design.

2774
Breihan, R. R., Daniels, Farrington, Duffie, J. A. and Lof, G. O. G. PRELIMINARY TESTS OF A SOLAR HEATED THERMOELECTRIC CONVERTER. 7 p., New York, United Nations, May 17, 1961. (E/CONF. 35/S/103)

Preprint of paper prepared for United Nations Conference on New Sources of Energy, Rome, 1961.

Preliminary data are reported on the production of electric currents by focussed sunlight on a thermoelectric converter made at the laboratories of the Westinghouse Corporation.

The collector with aluminized mylar on a plastic parabolic reflector 6 feet in diameter focussed less than 50 percent of the intercepted solar radiation on the converter which was 5 inches square.

The converter received 16 kilocalories of heat and gave up 12 kilocalories of heat to the cooling water while producing a maximum of 40 watts of electricity at low voltage. Some of the ways in which improvements can be made are pointed out.

2775
Daniels, Farrington. PRINCIPLES AND PROBLEMS IN THE UTILIZATION OF SOLAR ENERGY. In Conference on Solar Energy: The Scientific Bases, Tucson, 1955. Transactions, p. 37-40, Tucson, University of Arizona, 1958.

A general survey dealing with the amounts of solar radiation available, physical principles of its utilization, and the different classes and types of solar engines.

2776
Daniels, Farrington. SURVEY OF RESEARCH FIELDS AND NEEDS. Natl. Acad. Sci. Proc. 47:1245-1252, Aug. 1961.

In an introduction to the Symposium on Research Frontiers in Solar Energy Utilization, April 24, 1961, solar fuels, solar collectors, solar heating, selective radiation surfaces, storage of heat, solar cooling, heat engines, solid converters of

solar radiation into electricity and storage of energy are mentioned.

2777
Duwez, Pol. THE COLLECTION AND CONCENTRATION OF SOLAR ENERGY FOR THERMAL APPLICATIONS. In Seminar on Advanced Energy Sources, 1958, Proceedings...p. 123-126, Fort Monmouth, N. J. 1959? (Contract DA36-039-SC-78064) (PB 151461) (AD 209301)

Flat plate collectors and solar concentrators are considered in detail.

2778
Electro-Optical Systems, Inc., Pasadena, Calif. ANALYSIS OF SOLAR ENERGY UTILIZATION. Volume I. Part I. CONCLUSIONS AND RECOMMENDATIONS. Part II. SUBJECT INDEX, by J. H. Fisher. 38 p., Feb. 1959. (WADC Tech. Rept. 59-17, vl. 1, pts. 1-2) (Contract AF33(616)5564) (AD-214 611)

The conclusions and recommendations in developing solar energy for military applications are presented in concise form. These conclusions and recommendations are delineated both for specific devices and applications. Pertinent devices and applications are briefly discussed. A complete subject index for all the material is included.

2779
Electro-Optical Systems, Inc., Pasadena, Calif. ENERGY CONVERSION SYSTEMS REFERENCE HANDBOOK. Volume II, SOLAR-THERMAL ENERGY SOURCES, by D. H. McClelland and C. W. Stephens. 408 p., Sept. 1960. (WADD Tech. Rept. 60-699, vl. II) (Contract AF33(616)6791) (AD-256 973) (PB 171 859)

Basic problems in development of lightweight, high efficiency, solar concentrating mirrors for space power systems, concentrator and absorber design are discussed.

2780
Farber, E. A. SELECTIVE SURFACES AND SOLAR ABSORBERS. Solar En. 3:9-13, diags., Apr. 1959.

This paper deals with the emission characteristics of the sun and artificial radiation sources, the absorbing and transmitting properties of materials, and how these properties of materials can be analyzed and used to advantage in solar energy collectors. The actual performance of these surfaces is predicted from spectral data and then compared with actual results obtained with artificial sources indoors and the sun as source outdoors.

2781
Gier, J. T. and Dunkle, R. V. SELECTIVE SPECTRAL CHARACTERISTICS AS AN IMPORTANT FACTOR IN THE EFFICIENCY OF SOLAR COLLECTORS. In Conference on the use of Solar Energy: The Scientific Basis, Tucson, 1955. Transactions, vl. 2, p. 41-56, Tucson, University of Arizona, 1958.

Discussion on selective spectral characteristics of materials as evaluated from experimental data revealing the fact that most thermal radiators and absorbers differ greatly from perfect radiators both totally and spectrally; this latter phenomenon can be used advantageously in improving the efficiency of solar absorbers. Sample spectral data are presented. A simple analysis of the efficiency of a solar absorber from a radiometric point of view is included.

2782
Gillette, R. B. SELECTIVELY EMISSIVE MATERIALS FOR SOL SOLAR HEAT ABSORBERS. Solar En. 4:24-32, figs., Oct. 1960.

Research was aimed at obtaining selectively emissive materials for solar heat absorbers. A theoretical analysis was made of absorber-surface efficiencies and selective absorber materials were

prepared and tested. The theoretical analysis showed that selective absorbers do have an efficiency advantage over black-body surfaces at temperatures up to 2000°F. Two good selective coatings were developed - a cobalt-oxide deposit and a chrome-nickel-vanadium deposit. The coatings were applied to both polished copper and nickel. The cobalt-oxide surfaces produced an absorptivity of 0.93 and an infrared emissivity of 0.24. The chrome-nickel-vanadium surface had an absorptivity of 0.94 and an infrared emissivity of 0.40.

2783
Henderson, R. E. and Dresser, D. L. SOLAR CONCENTRATION ASSOCIATED WITH THE STIRLING ENGINE. In Snyder, N. W. ed. Space Power Systems, p. 219-250, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

Progress is described in the development of a lightweight Fresnal reflector for the Stirling engine. Reasons for choosing the Fresnal configuration are listed.

Also issued as ARS Paper 1312-60.

2784
Hippel, von A., et al. TRANSFORMATION OF SOLAR ENERGY. Am. Acad. Arts & Sci. Proc. 79:319-322, Jly. 1951.

Discussion of possibilities of chemical and electrical converters.

2785
Hottel, H. C. PERFORMANCE OF FLAT-PLATE SOLAR ENERGY COLLECTORS. In Space Heating with Solar Energy, p. 58-71, Cambridge, Massachusetts Institute of Technology, 1954.

Description of solar collectors, development and use of performance quation, collector losses, heat-capacity loss, effect of tilt and efficiency of collectors.

2786
Hottel, H. C. and Woertz, B. R. THE PERFORMANCE OF FLAT-PLATE SOLAR HEAT COLLECTORS. Am. Soc. Mech. Engrs. Trans. 64:91-104, 1942.

Comprehensive study involving experimental and theoretical evaluations of flat-plate heat collectors for converting solar energy into hot water. Heat transfer and light transmittance into the collector are analyzed and experimental results given.

2787
Hottel, H. C. and Unger, T. A. THE PROPERTIES OF A COPPER OXIDE-ALUMINUM SELECTIVE BLACK SURFACE ABSORBER OF SOLAR ENERGY. Solar En. 3:10-15, figs., Oct. 1959.

Also issued as Publication 71 of the M.I.T. Solar Energy Conversion Project. This paper is based largely on an Sc.D. thesis submitted in May 1958, by T. A. Unger, to the Massachusetts Institute of Technology.

The flat-plate solar energy collector is the simplest type of collecting device, and, in the opinion of its proponents, the only one which is economically feasible at the present time. Essentially it consists of a blackened absorber plate to which are attached tubes or fins for energy removal. The blackened side exposed to the sun is covered by one or more parallel air-spaced glass plates to reduce energy losses to the surroundings.

To examine the structure of thin selective black layers on shiny metal as well as to study the variables in the production of such films with the hope of improving the selectivity, the system copper oxide-aluminum was chosen for study. In the experiments described here, the oxide was produced by nitrate spraying and subsequent thermal decomposition.

2788
Klass, P. J. SOLAR ENERGY COULD DRIVE SPACESHIP'S ELECTROSTATIC POWER DRIVE, IRE HEARS. Aviat. Wk. 62:76-82, illus., Apr. 25, 1955.

An electrostatic power plant fueled by the sun's energy may power spaceships, according to Dr. Ernst Stuhlinger, ex-German rocket scientist. The ship would carry 40 or more large parabolic reflectors for converting solar energy into electric power.

2789
Liu, B. Y. THE CHARACTERISTICS OF SOLAR RADIATION AND THE PERFORMANCE OF FLAT-PLATE SOLAR ENERGY COLLECTORS. PhD Thesis, 96p., Minnesota University, 1960.

The performance characteristics of flat-plate solar energy collectors are treated in Chapter 2 where the main objective is to develop a generalized method of predicting collector performance. The basic approach of Hottel and Whillier is followed. The characteristics of the "utilizability" in the performance equation is studied in detail and a set of generalized curves is presented by means of which the performance of flat-plate solar energy collectors at any locality can be predicted without requiring detailed solar radiation records. The utilizability at any locality for collector of any orientation is shown to be a function of three dimensionless parameters each of which are easily determined. A simplified performance equation is developed which permits rapid determination of collector performance and gives results of sufficient accuracy for engineering use. Sample performance curves for different collectors at selected localities are constructed and compared. (Dissertation Abs. 21:3403, 1961)

2790
Lockheed Aircraft Corp., Sunnyvale, Calif. MECHANICS PROBLEMS OF SPACE FLIGHT, by W. E. Johnson, G. B. Cline, Jr. et al. 1 vl., illus., Nov. 16, 1959. (Rept. LMSD 288073) (AD-231 349)

A need is shown to exist for large-area low-mass structures for use in orbiting and space vehicles. Specific applications of these structures to orbiting vehicles include passive communications antennas, optical reflectors, and radiation collectors for solar boilers and solar batteries; applications to space vehicles include those mentioned previously plus solar sails for propulsion or vernier guidance control purposes. The dynamics problems treated included a study of the maneuvering tacking motions of a solar-sail space ship. It is found that for small payloads (~100 pounds earth weight), a relatively small amount of energy is required to maneuver the solar sail.

2791
Löf, G. O. G. PROFITS IN SOLAR ENERGY. Solar En. 4:9-15, figs., Apr. 1960.

Solar energy applications are examined from the point of view of their profit-making potential. The study is based on a consideration of the availability and characteristics of solar energy, the sources of profit in conventional energy sources, and the type of industry which could participate in the commercialization of solar energy. Solar equipment now being manufactured is of four types -- water heaters, batteries, cookers, and toys and novelties. Three types of solar energy equipment now in the development stage are seen to have early commercialization prospects. The largest market during the present century will likely be residential heating and cooling systems. Technical or economic considerations will limit several applications such as commercial electricity from solar energy and capture and storage by photochemical means.

2792
McClelland, D. H. SOLAR CONCENTRATORS FOR HIGH TEMPERATURE SPACE POWER SYSTEMS. In Snyder, N. W. ed. Space Power Systems, p.129-152, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

Basic problems in the development of light-weight, high efficiency, solar concentrating mirrors for space power systems are discussed.

Also issued as ARS Paper 1314-60.

2793
Marcus, R. J. CHEMICAL CONVERSION OF SOLAR ENERGY. Sci. 123:399-405, Mar. 9, 1956.

Collection, conversion, storage, generation and application aspects are considered from the viewpoint of available facts. A bibliography of 49 references is included.

2794
May, J. R. THE EFFECT OF ENVIRONMENT ON THE DESIGN OF A SOLAR CONCENTRATOR. In Institute of Environmental Sciences. Proceedings 1960, p. 419-424, Mt. Prospect, Ill., The Institute, 1960.

The use of solar energy for space vehicles is the primary subject.

2795
Miles, F. G. COOLING WITH SOLAR ENERGY. Inst. Heat. Vent. Engrs. J. 27:97-107, Jly. 1959.

Survey of techniques, design features and operating characteristics of collection equipment; use of collected heat to produce cold for air conditioning purposes or process cooling; description of Electrolux domestic refrigerator and intermittent systems. It is concluded that solar energy is useful for air conditioning purposes in several parts of the world, and suitable low cost equipment would improve living conditions in tropical countries. (Eng. Index p. 1222, 1960)

2796
Miller, Barry. UNFURLABLE SOLAR COLLECTOR IS DEVELOPED. Aviat. Wk. & Space Tech. 75:81, 83, illus., Aug. 14, 1961.

An unfurlable solar collector, capable of gathering in sun's rays and focusing them onto an absorber at its focus, consists of 18 electroformed nickel petals which can be unfurled from folded configuration into parabolic collector, 52-in. in diameter. Feasibility model was made by Electro-Optical Systems, Inc., Pasadena, Calif.

2797
Morse, R. N. and Czarnecki, J. T. THE FLAT-PLATE ABSORBER AS A SOLAR ENERGY COLLECTOR. Paper presented at the ANZAAS Congress Solar Energy Symposium, Adelaide, Australia, Aug. 25, 1958. 10p., illus.

The elements of a flat-plate absorber and the factors influencing its design and operation are reviewed. The thermal characteristics of energy received, losses, efficiency, and the heat transfer to the circulating fluid are dealt with in the light of design consideration. The effect or orientation and its influence on the evaluation of energy incident on inclined surfaces, the optimum angle of inclination, and the effect of changes in azimuth is considered. Installation and operating problems such as the prevention of damage by freezing, protection from hail, the location of an absorber and its materials of construction and economic factors are discussed. (Solar Eng. 3:41, Apr. 1959)

2798
National Aeronautics and Space Administration, Washington, D. C. MEASUREMENTS AND CALCULATIONS OF THE EFFECTS OF DISTORTIONS IN THE COLLECTOR SURFACE ON EFFICIENCIES OF UMBRELLA-TYPE SOLAR COLLECTORS, by V. R. Bond. 44p., Aug. 1961. (Tech. Note D-925) (AD 261 701)

The distortions caused by meridional and transverse tensions in the reflecting surface of an umbrella-type solar collector and the effect of these distortions on the efficiency of the collector are analyzed. (Solar collectors of 30, 60, and 90 ribs and with rim angles of 45° and 90° are considered.)

2799
Oklahoma University Research Institute, Norman, Okla. THE USE OF

PLASTIC COVERS FOR FLAT-PLATE SOLAR ENERGY COLLECTORS, by G. L. Hitt. 1 vl., illus., 1959. Master's thesis. (AD-218 893)

A method of using solar energy is described for domestic hot water and building heat. The method is called the flat-plate collector. A cover or glazing material allows the collector to receive the solar energy with a minimum of loss by absorption, reradiation, or conductance. The cover or glazing material has to be transparent to the solar spectrum and opaque to long, or infrared, wavelength radiation. New plastic films are being developed as glazing for solar energy absorption collectors. A comparison is made between some plastic films and glass covers for flat-plate collectors.

2800
Penrod, E. B. and Prasanna, K. V. SOLAR ENERGY FOR FUTURE HEAT PUMPS. In American Power Conference. Proceedings, Mar. 29-31, 1960, Chicago, Ill., vl. 22, p. 477-490, Chicago, Illinois Institute of Technology Press, 1960.

This paper is the result of extensive calculations made to determine the performance of a heat pump system using a ground coil and a solar collector as heat sources.

2801
LA RECUPERATION DE L'ENERGIE SOLAIRE: PROBLEMES PHYSIQUES ET ASPECTS ECONOMIQUES. (RECUPERATION OF SOLAR ENERGY: PHYSICAL PROBLEMS AND ECONOMIC ASPECTS). Acta Electron. 3:83-186, Apr. 1959.

In French. Contents include, among several discussions: Solar Radiation, by E. Vassy, p. 83-102; Conversion of solar energy, by H. Masson, p. 103-142. (Astron. Info. Search 294)

2802
Shaffer, L. H. WAVELENGTH-DEPENDENT (SELECTIVE) PROCESSES FOR THE UTILIZATION OF SOLAR ENERGY. Solar En. 2:21-26, illus., Jly/Oct. 1958.

The theoretical maximum work obtainable from solar-powered selective absorber thermal devices is calculated. Selective thermal devices are compared with quantum devices and the optimum cut-off wave-lengths and other operating parameters are calculated for both types of device. Selective thermal devices are capable of an exceedingly high overall efficiency. Theoretically, as much as 55 per cent of the average sunlight received at the earth's surface may be converted to useful work. The effects of imperfect absorbing and reflecting surfaces and the effects of small convection and conduction losses are considered briefly.

2803
Silvern, D. H. AN ANALYSIS OF MIRROR ACCURACY REQUIREMENTS FOR SOLAR POWER PLANTS. In Snyder, N. W. ed. Space Power Systems, p. 111-127, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4)

The mirror accuracy required to collect solar energy in a substantially black cavity at various temperature levels is investigated.

Also issued as ARS Preprint 1127-60.

2804
SOLAR THERMOELECTRIC GENERATOR. Chem. Wk. 85:43, Jly. 4, 1959.

A thermoelectric generator powered by solar energy was unveiled last week by a team of Westinghouse and Boeing engineers. Proposed for long-mission satellites and space vehicles, the unit requires a large mirror-like device -- similar to a solar furnace -- to collect and concentrate the sun's energy. A 3-lb, 20-in. long bench model of the new generator develops sufficient power (about 2.5 watts) to operate a radio transmitter.

2805
A STATIONARY SOLAR ENERGY CONCENTRATOR. Solar En. 3:65-66, Dec. 1959.

A parabolic reflector having a short focal length will keep the sun's rays focused within a small area for several hours without the employment of a heliostat mechanism. Its use as a steam generator and as a stove is described.

2806
SUNFLOWER IN SPACE: POWER FROM PROVED HARDWARE. Mach. Design 33:14, illus., Apr. 27, 1961.

Basis of this short article is a statement by C. J. Daye of Thompson Ramo Wooldridge Inc., Tapco Group, to the effect that "auxiliary-power-systems based on the Sunflower concept (hinged 'petals' unfolding to form a parabolic solar collector) may be the most practical first-generation method of producing electricity in space."

2807
Tabor, H. SOLAR COLLECTORS, SELECTIVE SURFACES, AND HEAT ENGINES. Natl. Acad. Sci. Proc. 47:1271-1278, Aug. 1961.

An indication is given of some of the areas where progress has been made in thermal conversion of solar radiation and some pointers for future work.

2808
Tabor, H. SOLAR ENERGY COLLECTOR DESIGN, WITH SPECIAL REFERENCE TO SELECTIVE RADIATION. Res. Counc. Israel. Bull. 5C:5-27, figs., Nov. 1955.

The possibility of making solar energy collectors of high efficiency by use of selective black surfaces has prompted a re-statement of the problem of collector design. By means of two parameters, the overall transmission efficiency and the cut-off intensity, it is possible to determine the performance of a collector under various conditions of use. The concept of retention efficiency permits the construction of generalized yearly average efficiency curves from which the influence of a change in some design parameter is quickly seen. Computations show that it should be possible to produce low pressure steam without optical concentration, and high pressure steam with a small degree of concentration.

2809
Tabor, H. STATIONARY MIRROR SYSTEMS FOR SOLAR COLLECTORS. Solar En. 2:27-33, figs., Jly/Oct. 1958.

An angle in solar geometry termed the EWV altitude is defined, and its variation with time and season is shown. This variation indicates the necessary acceptance angle of a stationary mirror system for solar collectors. It is shown that a completely stationary mirror cannot give any useful concentration, but that if the tilt is varied with the seasons, an east-west cylindrical parabolic mirror without diurnal movement can yield a concentration of approximately three. This may be increased to about four with the aid of a small auxiliary (fixed) mirror to provide a second stage of optical concentration.

2810
THIN MIRRORS PLAY FIVEFOLD ROLE WHEN HARNESSED SUNLIGHT PRODUCES ELECTRICITY. Steel 148:111, Feb. 13, 1961.

Information is given relative to an improved solar power converter developed by R. C. Schlichtig.

2811
Tinsley, Frank. FLIGHT TO THE STARS ON SUN POWER. Mechanics Illus., p. 72-77, illus., Jan. 1956.

In space ship designed by Dr. Ernst Stuhlinger, power is supplied by 40 solar power units mounted in two groups on either side of ship's body.

Each solar unit consists of a parabolic mirror, 50 feet in diameter, which concentrates the sun's heat on a boiler at its focus.

2812
Touchais, M. ECONOMIC STUDY OF THE OPERATION OF ATMOSPHERIC SOLAR COLLECTORS IN THE SAHARA. 30p., figs., New York, United Nations, Apr. 20, 1961. (E. CONF. 35/S/45)

Preprint of a paper prepared for the United Nations Conference on New Sources of Energy.

The Institute of Solar Energy, University of Algiers, has envisaged the large-scale generation of hot air, which might be used for various purposes, such as air conditioning, power generation, or as a heat sink to circulate air for cooling thermoelectric generators. Against this background the author takes up two problems: (1) a study of a complete large-area plant using atmospheric solar collectors of a specified type; (2) a comparative experimental study of various collector types.

2813
Trombe, Felix, Foex, Marc, and La Blanchètais, C. H. FOUR SOLAIRE POUR LA REALISATION DE TRES HAUTES TEMPERATURES. (SOLAR FURNACE FOR OBTAINING VERY HIGH TEMPERATURES). Acad. Sci. Paris. Compt. Rend. 223:317-319, 1946.

In French. First paper by Trombe and his collaborators on concentrating solar radiation by means of parabolic mirror and an application to fusion of oxides and metals.

2814
Trombe, Félix, Foex, Marc, and La Blanchètais, C. H. FOURS À ACCUMULATION D'ENERGIE SOLAIRE. (FURNACES FOR THE ACCUMULATION OF SOLAR ENERGY). Acad. Sci. Paris. Compt. Rend. 231:44-46, illus., Jly. 3, 1950.

In French. Solar furnace with a parabolic mirror of 600 sq cm surface area produces a temperature of 1460°C at its focus. Temperature radiation from the material of the mirror itself is an important cause of heat loss. The mirror of 53 sq cm area gave a temperature of 2600°C; one of 1750 sq cm, a temperature of 1070°C.

2815
USE OF SOLAR ENERGY. Power Eng. 65:55, Jan. 1961.

Characteristics of solar radiation are mentioned including methods for converting solar energy into heat. Types of solar collectors and reflectors are briefly described. Mention is also made of conversion of energy into electricity with semiconductor materials such as the silicon cell.

2816
Veinberg, V. B. OPTICS IN EQUIPMENT FOR THE UTILIZATION OF SOLAR ENERGY. 257p., Moscow, State Publishing House of Defence Industry 1959.

In Russian. U.S. Atomic Energy Commission Trans. 4471.

Ch. 4 is on Concentrators of Solar Rays.

2817
Vliet, R. M. SELECTIVE COATINGS FOR EXTRA-TERRESTRIAL SOLAR ENERGY CONVERSION: A FUNDAMENTAL ANALYSIS. In Coatings for the Aerospace Environment, Proceedings of Meeting, Wright Air Development Division, November 9-10, 1960, p. 10. (WADD TR 60-773).

This report discusses the role of solar energy in the overall problem of secondary power generation for space vehicles. The principal technology needed for the successful use of solar power is that of achieving high solar energy collection efficiency. The optical variables entering into coatings for the collection of solar energy are

analyzed and expressed in graphical form suitable for future use. The result of this analysis leads to a graph of collection efficiency vs. temperature which completely characterizes a coating for solar power generation. This study points up the need for coatings with high solar energy absorption, α, as well as high α to ϵ ratios. The fundamental principles of energy absorption and reflection are discussed with reference to metallic and dielectric materials. The application of these principles to selective coatings is discussed and illustrated.

2818
Wing, L. D. and Cameron, K. E. SOLAR COLLECTORS FOR USE IN THERMIONIC POWER SUPPLY SYSTEMS IN SPACE. ARS J. 31:327-334, Mar. 1961.

The optical aspects of a solar-thermionic power system are described. Various design considerations are presented along with an analytical approach. A modular concept is proposed, and definitions of the problem areas, such as collector fabrication, are followed by an engineering approach to the system design in which a method is presented to decrease the stringent solar alignment tolerance.

2819
Yellott, J. I. PROGRESS REPORT: SOLAR ENERGY IN 1960. Mech. Eng. 82:41-44, Dec. 1960. Excerpts - Combustion 32:57-58, Dec. 1960.

Discusses silicon solar cells, vapor cycle solar power units, thermionic and thermoelectric converters, photosynthesis for food and oxygen, solar energy system components, solar energy systems for ground use, including sea-water distillation and solar furnaces.

IX. REGULATION AND CONTROL

2820
Alekseeva, G. E. and Melishkina, L. P. USE OF THE HALL EFFECT FOR CONVERTING DIRECT TO ALTERNATING CURRENT. Pribory i Tekh. Eksp. no. 2, p.100-103, Mar/Apr. 1958.

In Russian. Trans. in Instr. Exp. Tech. (USSR) no. 2, p.289-290, Mar/Apr. 1958.

The use of the Hall effect is considered for conversion of a constant voltage of small magnitude into an alternating one. In order to increase sensitivity a method is proposed for lowering the parasitic emf's induced in the semiconductor transducer, by means of the introduction of compensating counter-emf's, and the use of a selective transistorized amplifier. Experimental data are given for the conversion d.c. voltages of about 10 to 50 μv into sinusoidal voltages. (Sci. Abs. 64B; 1926, 1961)

2821
Bills, G. W. SPACE ELECTRIC POWER TRANSMISSION. AIEE Paper CP-59-861, presented June 21-26, 1959. New York, American Institute of Electrical Engineers.

The subject of this paper is power transmission exploiting conventional techniques such as power cables. It is determined that space electric power transmission lines will be made of aluminum with a rectangular or ribbon cross section. Direct-current operation of the lines appears to be desirable, expecially so when thermoelectric generators for converting nuclear energy to direct-current electricity becomes available. (Astron. Info. Lit. Search 294, p.29)

2822
CONVERSION OF DC TO AC. Power Eng. 65:71-72, Jan. 1961.

The two-part problem is explained, involving magnitude and voltage. Development of solid state conversion equipment is mentioned, particularly a device termed Trinistor.

2823
Moll, W. J. H. A RELIABLE THERMO-CONVERTER. J. Sci. Instr. 3:209-210, 1926.

Description of apparatus for transforming alternating current into direct current by means of the thermoelectric effect. In combination with a good milli-voltmeter, it forms an instrument of high precision for alternating current measurements. (Exp. Wireless & Wireless Engr. 3:387, June 1926)

2824
Storm, H. F. and Shattuck, D. P. TUNNEL DIODE D-C POWER CONVERTER. Comm. & Electron. no. 55, p. 347-352, diags., Jly. 1961.

The tunnel diode d-c converter serves to generate direct current of a desired potential, when the d-c supply is only a fraction of 1 volt, as may be encountered in connection with silicon solar cells; thermoelectric, thermionic devices; chemical fuel cells; and others. Not only will this paper describe such a converter but also demonstrate how to analyze circuit problems involving a highly nonlinear device, such as a tunnel diode; furthermore how, by intensifying a nonlinearity, the analysis of a nonlinear problem becomes simpler. The price paid for this simplification is reduced accuracy, but this price often appears attractive because of the radical problem-simplification which can be realized.

2825
Temco Electronics and Missiles Co., Dallas, Tex. INVESTIGATION OF SILICON CONTROLLED RECTIFIERS FOR STATIC POWER CONVERSION, by G. P. Underbrink. 2 issues, Feb. 20, Mar. 20, 1961. (Repts. TER 611.1901A, TER 611.1905) (Quart. Prog. Repts. 1, 2) (Contract DA36-039-sc-85381)

The specific objectives have been to determine the most promising methods of dc-to-ac power inversion using the SCR, to study associated problem areas, and to recommend and program their solutions.

AUTHOR INDEX

DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS. Compiled in the Library Branch, Technical Information Division, U.S. Naval Research Laboratory. 233 pages. April 1962. A collection of references from various sources covering the current literature on thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources.	1. Direct Energy Conversion – Bibliography 2. Thermoelectricity Bibliography 3. Thermionic Emission – Bibliography 4. Magnetohydro-dynamics – Bibliography 5. Energy Sources – Bibliography I. Benton, Mildred	DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS. Compiled in the Library Branch, Technical Information Division, U.S. Naval Research Laboratory. 233 pages. April 1962. A collection of references from various sources covering the current literature on thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources.	1. Direct Energy Conversion – Bibliography 2. Thermoelectricity Bibliography 3. Thermionic Emission – Bibliography 4. Magnetohydro-dynamics – Bibliography 5. Energy Sources – Bibliography I. Benton, Mildred
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